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**Embedding Cognitive Systems into Systems  
Engineering Practice**

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**FOR THE DIRECTOR**

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14. ABSTRACT Research and Development of the Acquisition Practitioner Support Environment (APSE) is described. Product is a web-enabled guide to in-engineers, human systems engineers/integrators and cognitive engineers. Deliverables were selected for value in incorporating human abilities, limitations, preferences and costs in development, operations and sustainment activities. APSE instantiates a model process the goal of which is to provide improved mission performance and reduced total ownership costs. Also described are efforts to create market for the product. These activities involved creating awareness of human systems integration and cognitive engineering value in systems engineering and project/program management communities.					
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# 1. Summary

Air Force AF05-071, “Embedding Cognitive Systems into Systems Engineering Practice,” had the following objective: “Develop a process and toolset to embed the application of the emerging practices and technologies of cognitive systems into the traditional practice of systems engineering.”

The topic was interpreted to address a pernicious and tenacious problem. The failure to include human characteristics, needs, and cost influences within the development, operations and sustainment cycle was resulting in failed systems, products people refused to use, and soaring operations costs. Research showed the problem had been around for at least 50 years; we believe the duration is closer to 150 years. It is intensifying as the prominence and ubiquity of software-driven products and systems increases. We resolved to use the contract opportunity to retire the problem. Challenges to retiring the problem were two-fold. They can be related to the process and the toolset.

## 1.1. Challenges

Process Challenges. Three separate contractors were ostensibly developing three different processes. If the develop processes were not identical, which would be deemed correct? Would someone be forced to pick and choose from the offerings to select one in whole or several parts that would somehow be later integrated? Additionally, neither the contractors nor the sponsor owned the systems engineering process. Several organizations or professional societies, the International Standards Organization (ISO), IEEE, and the International Council on Systems Engineering (INCOSE), have produced standards and handbooks which authoritatively capture the systems engineering process. It is upon these standards that the Defense Acquisition System (DAS) squarely rests. If the problem were to be retired, changes to authoritative documentation would need to be agreed upon and adopted.

Toolset Challenges. Post-phase-II commercialization of the product or service, in this case the toolset, is a goal of the SBIR program. Investigations revealed an absence of a market for a toolset. In part this was because of interpretations of the term “toolset” that differed between disciplines. In part this was due to the lack of a recognized need.

To a systems engineer, a toolset is a collection of software that aids in analysis, definition and management; simulations and requirements and configuration management software are examples. To a cognitive engineer or a human systems integrator, a toolset is a collection of methods or procedures for performing knowledge elicitation, task analyses, or workload and manpower assessments, as examples. Contrast a systems engineering simulation, a computer program that performs mission analysis in support of requirements development with a cognitive walkthrough, a verbal simulation in which a storyboarded scenario undergoes stepwise review and the situation is clearly revealed. The first is an electronic product, and the second is an interpersonal communication.

Cognitive engineering methods do not lend themselves to coding. They are interactive investigations between engineer and subject. Practicing cognitive engineers have their own tools which they evolve and refine. They are not in the market for a software product.

Systems engineers, on the other hand, are interested in software products. Most practitioners are unaware of the definition, scope of application, and limitations of cognitive engineering. They are, for the most part, not aware of the need for cognitive engineering. Contractual cognitive engineering requirements are rarities; when they do appear, they are not considered system drivers.

Thus the greatest challenge for the toolset was not to develop one, but to create a market for one. Without awareness and demand, any toolset created would languish.

## **1.2. Two-Fold Solution**

A two-pronged solution was developed to address the two challenges. The first was a noncontract solution, a company investment in the founding and development of the INCOSE Human Systems Integration Working Group (HSIWG). The contracted work represented the second solution. This was the development of the Acquisition Practitioner Support Environment (APSE), a free toolset for bringing together the acquisition stakeholders necessary to achieving the implicit topic goal.

### **1.2.1. HSIWG**

The lack of awareness and demand for cognitive engineering extends to program and project managers. These acquisition stakeholders have little incentive to include cognitive engineering scope in program plans. We found that this situation is not unique to cognitive engineering. Project managers, as represented by Project Management International (PMI), are working to document their value to their customers (1). Systems engineering practitioners complain they are hired too late and are perceived to add major cost with little value. The importance of the contributions of human systems engineers are increasingly being recognized by the owners of capabilities (systems), but owners are unable to articulate this value in an executable fashion.



Figure 1: Acquisition stakeholders -- self-isolated from users and from one another

Figure 1 represents the situation. Each of the stakeholders addressed in this project – program and project managers, systems engineers, human system integrators and cognitive engineers move in their own circles. Their work, their research and publications are inwardly focused on their own needs, their esoteric professional jargon, and their own communities of practice. This is particularly damaging for the human systems integration (HSI) disciplines because many of its contributing domains – manpower, personnel, training, human factors, occupational health and safety – are separate disciplines unto themselves. We found that in the case of training, for example, practitioners of that discipline are unaware of their relationship to the integrating discipline, and to the developmental tradeoffs that impact their operational influence and contributions to total ownership cost.

The view in figure 1 is the 20<sup>th</sup> Century situation in miniature. The 20<sup>th</sup> century was the age of specializing. Specialists worked independently to improve the practice of their discipline, its influence, and its employment rates. These are the goals of the 20<sup>th</sup> century professional organization.

The HSIWG was formed to provide a forum wherein interdisciplinary discussions could take place. Systems engineers, members of the host organization engaged human factors engineers, human systems integration practitioners, cognitive engineers and members of IEEE Systems, Man and Cybernetics. Interdisciplinary and cross-organizational exchanges occurred. Member representatives from the Air Force Human Systems Integration Office and its 711<sup>th</sup> Command Wing, MANPRINT (U.S. Army) and the Navy's human systems integration office opened bidirectional lines of communication.

The organization began by developing a charter, a vision statement and a definition of human systems integration. Body material and a human systems integration appendix was submitted to and accepted for the INCOSE Systems Engineering Handbook version 3.0 (2). The IEEE 1220 systems engineering standard (3), a more abstract document, already included human systems engineering throughout its text. This meant that authoritative documents from the largest professional organizations representing systems engineers prescribed the inclusion of human systems integration in the systems engineering process. This was a step forward, but did not serve to institutionalize the incorporation of human systems integration into systems engineering or into the systems engineering process.

Defense Acquisition Systems documentation, as represented on the Defense Acquisition University web site (4), called for human systems integration at the top level, but there remained no documentation on or community of practices for human systems integration or cognitive engineering. Additionally, senior systems engineers, those in the position to shape the implemented process do not feel the need to read handbooks or standards. They rely on their experience and customer requirements to guide their practice.

To address this, this contract's principal investigator co-edited a special edition of INCOSE *Insight* magazine (5), a non-juried magazine designed to quickly move best practices into the field. An article from the JPRINT office was included to provide descriptions of the services' human systems integration initiative as well authoritative statements of human systems

integration requirements that systems engineers would be encountering with ever greater prevalence in future procurements.

We assert Human Systems Integration is the conduit by which cognitive engineering will penetrate acquisition programs. Cognitive engineering contributes to the manpower, personnel, training requirements generation, habitability, survivability, and human factors components of human systems integration. Therefore a second special edition of Insight magazine, this one with a cognition theme, is in process with an April, 2009 publication date.

### 1.2.2. APSE

The HSIWG was formed to create a climate for the process required by the topic; it was to open a market for a toolset. APSE is a web-enabled software application that points up opportunities for joint practice among the system owner's program manager, the contractor's project manager, and systems engineers, human systems integrators and cognitive engineers representing the owner as well as those on the contractor team.

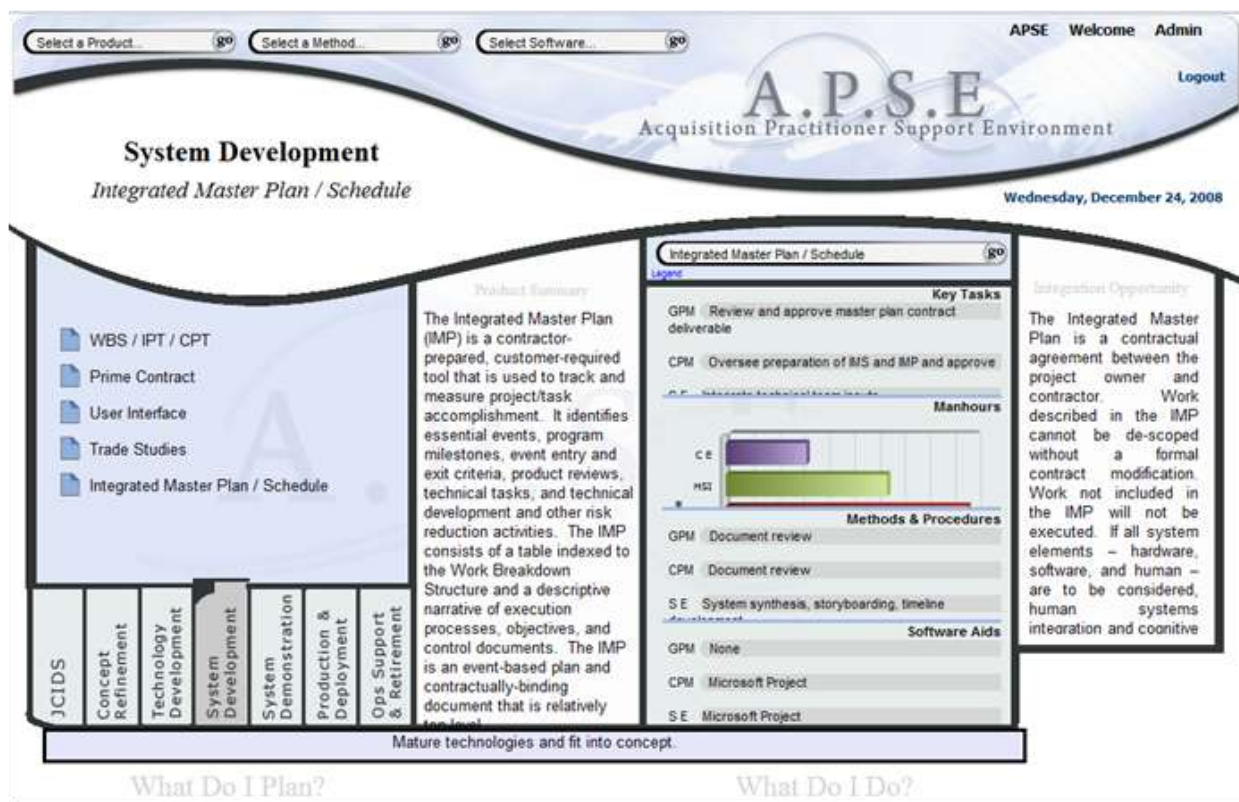


Figure 2: APSE main page

The APSE main page is shown in figure 2. The APSE interface was designed to be interesting and, to an extent, entertaining. This was to attract users and to encourage them to linger, to explore the material contained in the tool.

APSE text fields were purposefully word constrained. We found people were overloaded by weighty process documents and text books of systems engineering or task analysis. While one may assert that reading these documents is a necessary part of their jobs, we observed that people were not familiar with the material.

APSE assumes the six-phase DAS as the baseline system life cycle process. The Joint Capabilities Identification and Development (JCIDS) process was added as a seventh, precursor phase because of the importance of including human engineering during gap, needs, and solution analyses. When the phase is selected, a short description of the phase's purposes is displayed along the bottom bar.

For each of the seven phases shown on the left, five in-process deliverables were selected. In the figure 2 example, the System Development Phase includes the five deliverables WBS/IPT/CPT, Prime Contract, User Interface, Trade Studies, Integrated Master Plan / Schedule. Our investigations showed that systems will deliver better performance and lower total ownership costs because human systems integrators and cognitive engineers have contributed to these thirty-five deliverables.

The main page contains a succinct description of the product (first white field from the left) and a brief description of the integration opportunity the deliverable affords for interdisciplinary interaction (white field on right). These boxes allow scrolling when even a short explanation exceeded the field's size. Like many of the interface's fields, the box expands when clicked so the whole field can be seen at a glance. The font size grows with the expansion as well; this was a useful feature when investigators briefed the tool.

The accordion fields immediately to the left of the Integration Opportunity contain the most important tasks, estimates of man-time, and applicable methods and software for each of the five APSE customers. Tasks were selected to acquaint users with what they should be doing, but more importantly what other contributors are doing. Man-time is presented graphically as relative estimates; these were included to address project managers' concerns that the addition of human systems integrators and cognitive systems engineers would break their budgets. Methods help practitioners to develop a common lexicon; systems engineers did not know what to call the activities of cognitive engineers. Providing a reference enables them to consult on-line or textual references to learn more when they need to.

Software recommendations are meant to be exemplary of what is available to support the activities of APSE customers. At the beginning of phase II, we hypothesized those tools necessary to support the embedment of cognitive systems into systems engineering practice already existed. We set out to identify those tools and demonstrate some so APSE users could see how these software aids could be used as interdisciplinary communication devices.

APSE users seeking more detail can select a deliverable from the menu bar at top. They are then taken to the detail deliverable page (figure 3). On the top at the left, the deliverable page provides man-time estimates for instances when the deliverable is being developed as part of a major acquisition and for cases when the activity is being done as part of a focused effort. Input

and output conditions are provided for purposes of technical planning and earned value cost management.

On the right, Setting describes where the project or product is in its life cycle, what has been done and what needs to be done to generate the deliverable. Assumptions, below, describe what APSE investigators took for granted when putting together the deliverables page materials – often this field provided background for man-time estimates.

At the bottom, more expanded listings of tasks, methods and software are provided for each contributing discipline. This enables practitioners to get a more complete picture of their responsibilities at this point in the life cycle.

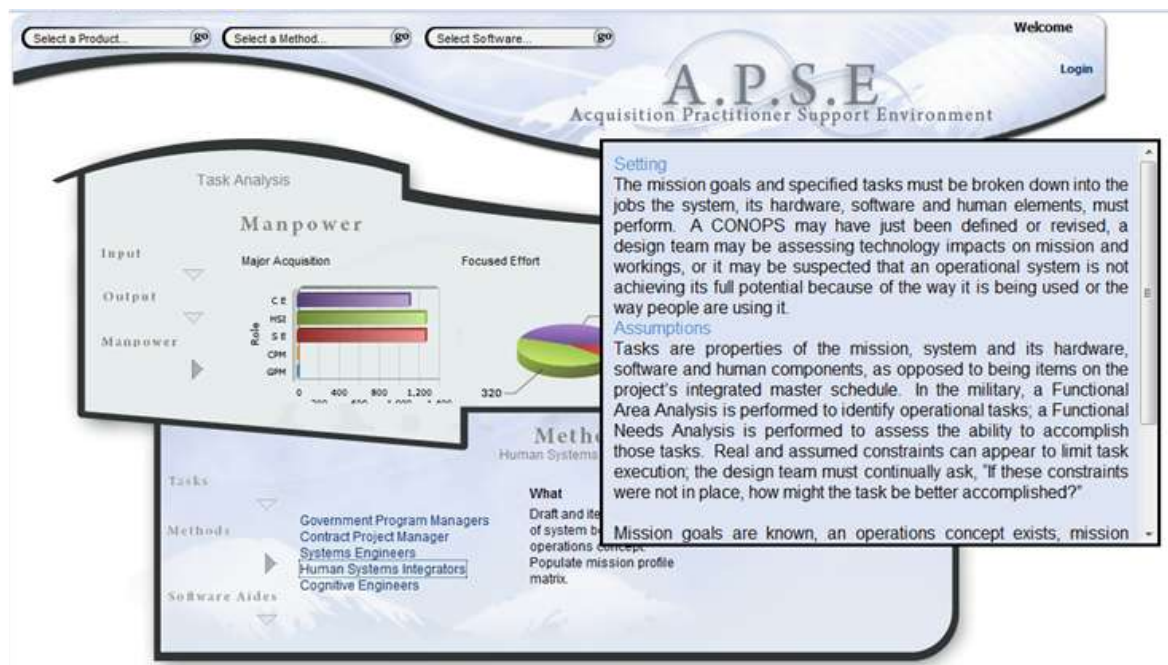


Figure 3: APSE deliverable page

Software was demonstrated for some of the most important human systems integration and cognitive engineering activities. Table 1 provides the software demonstrated and why it was selected.

Table 1: Software selected for demonstration

Software	Why software was selected
Micro Saint Sharp	Systems engineers would appreciate a simulation aid. The product can be used to depict scripted human interactions with products. Its engine underpins the Imprint human systems integration tool.
TestLog	Demonstrated human aspects of product testing that need to be documented as part of test planning, overseen during text execution and documented as part of post-test analysis.
Task Architect	Task bookkeeping software useful for capturing results of behavior and cognitive task analyses. Analogous to the systems engineering tools Doors, Core or Slate.



We used a product developed as part of another SBIR effort to document our experience with the software demonstration. The Geeksee interface is built upon the foundations of the abstraction-decomposition matrix of the cognitive work analysis approach to cognitive engineering.

Purposes, measures and goals are at the top, functions are in the middle moving downward and objects and details are at the bottom. Figure 4 provides an example for the TestLog software; the same format was used to document the results of all software demonstration

On the left, the purposes, functions and a link to the manufacturer's web page are listed. Purpose statements were written by project investigators. Functions were generally taken from manufacturer's literature. On the right, the goals of the software demonstration are given at the top. The demonstration steps are listed in cookbook fashion in the middle panel moving down. Each step has an associated artifact which is displayed in the center window when the step is clicked by the user. In the example, the TestLog page for the unit-level test has been clicked and the test description, anticipated results, actual results and analysis are shown. The center window expands to fill the display screen when selected allowing viewers to scroll through the material.

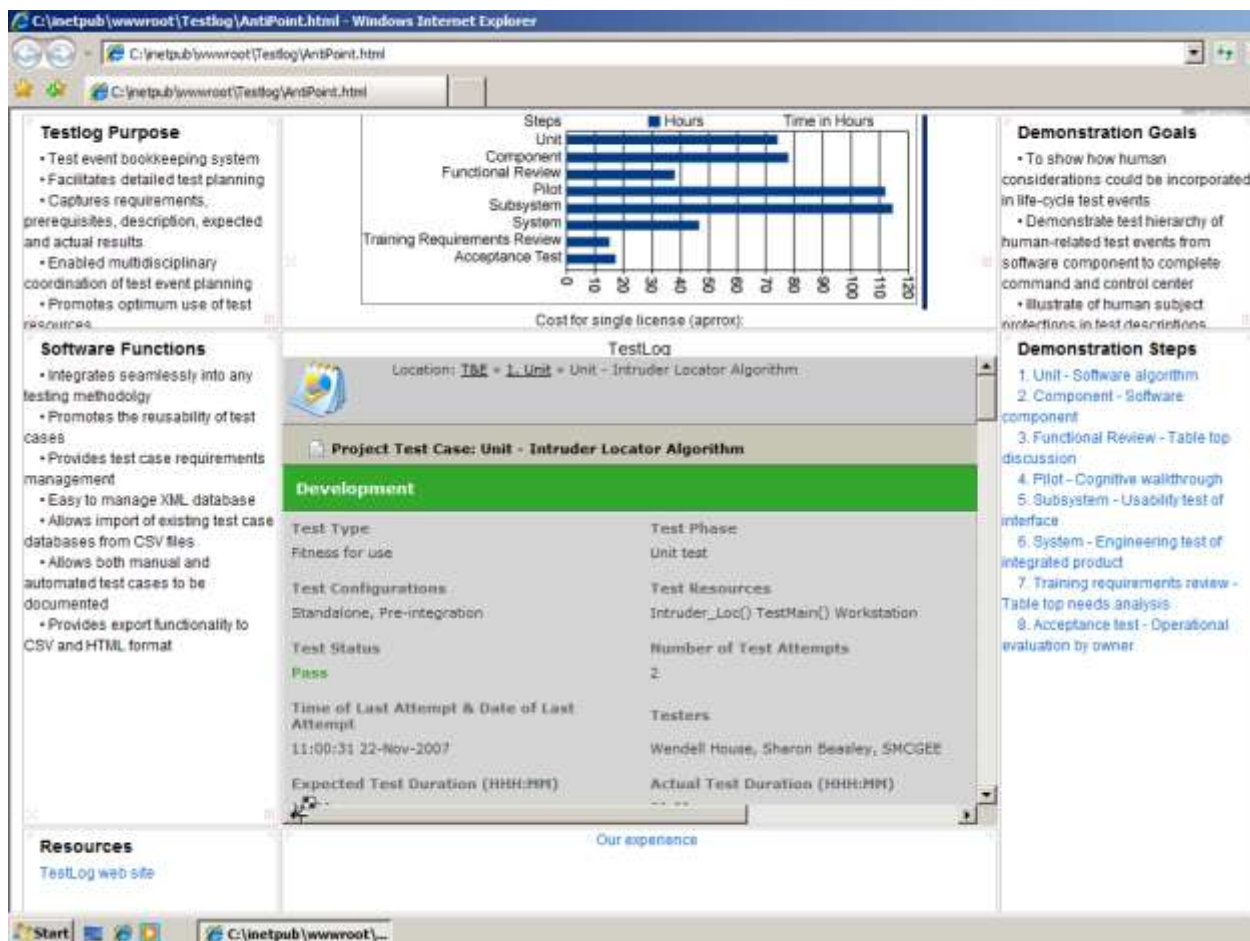


Figure 4: TestLog software as example of software aid page

For planning purposes, we have included costs of using the software at the top. Investigators noted the time it took to execute each of the software setup and demonstration steps. This time is included in graphic form. Below that, the price of the software is given. Prices are indicated by range so people thinking of purchasing the software know if it is around \$100 or in the \$5,000 to \$10,000 range for example.

At the bottom, is a link to a document that describes our experience in using the tool. The experience reports describe glitches, workarounds, and lessons learned. Some entries suggest improvements that would make the software more effective or usable.

### 1.2.3. Summary Findings and Conclusions

Figure 5 shows the target end state for the effort. In this vision, government and contractor program managers, project managers, systems engineering, human systems integrators and cognitive engineers work together alongside the specialty engineers – mechanical, electrical, civil, industrial, quality, etc. At the center of their considerations are the jobs users must do – manufacture, test, train, operate, maintain, supply, and train.

The work done to bridge disciplinary boundaries was successful within limits. INCOSE is working toward establishing a memorandum of understanding with Human Factors and Engineering Society. HSIWG representatives have been encouraged and empowered to engage the American Society of Safety Engineers. Meetings, sponsored by the cognitive engineering community, got acquisition personnel and those experienced with product development to sit across from researchers, trying to reach a meeting of the minds. Systems engineers have participated in cognitive engineering brown bag discussions on a monthly basis. We have shared the figure 5 vision with training and information technology providers. Papers have been written and presentations made.



Figure 5: Acquisition stakeholders collaborating, users receive focus

Nevertheless, practice remains personality based. The job of re-engineering a culture involves changing one mind at a time. People have to be at the table when discussions are held. It is not enough to write papers, practitioners need to recognize the applicability to their work and the

value they provide. When investigators presented APSE at the I/ITSEC, passersby were asked, “Does your work involve humans?” Most of the people responded, “No, I don’t do anything that has to do with people.” ‘I write middleware.’ ‘I do blast analysis.’ There is no recognition that someone is going to use that middleware to get two systems talking to one another, and that the middleware can be written so that the linking is easy, efficient and effective or impossibly complex and time consuming. Eventually that middleware will need to be updated, that task, too, could be easy to do or difficult. The design of the product and the user interface will have an impact on productivity and competitiveness. In military terms, this translates into superiority. The same can be said for the blast analysis. Someone will have to apply those data. How will it be used? What decisions will be based on the results?

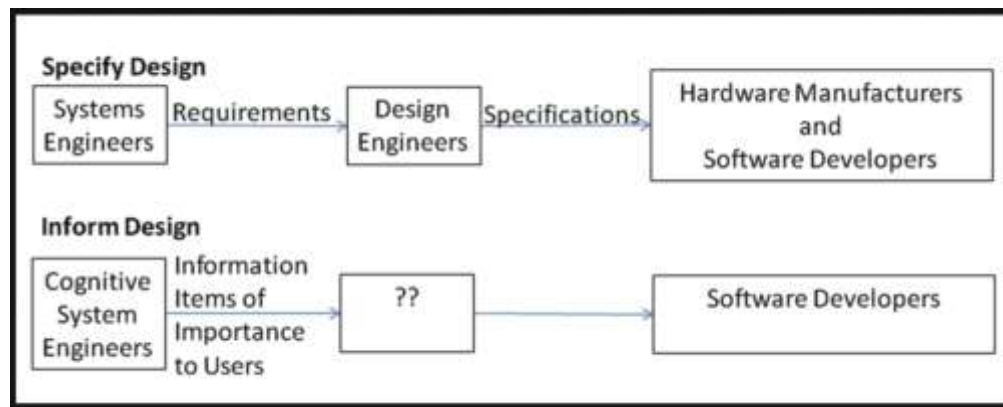


Figure 6: The missing link when design is informed

We established there was a function missing from the cognitive engineering to software manufacture process. In our effort, we supplied that piece with a graphic designer. More properly, for mission critical interfaces, that person is a human computer interface designer. The HCI expert appears to have the skills to translate user requirements developed by cognitive engineers into design specifications. This is the function responsible design engineers provide for systems engineers.

This finding was illuminating to the members of the cognitive engineering community with whom we interacted. It solved some of the riddles that were discovered in phase I about why software engineers were unable to use the products of cognitive engineering.

This was determined to be only part of the answer. Cognitive engineers also needed to learn about technical management processes, such as configuration management, in order to insert the requirements they discover into the development process. Configuration management is particularly important to a discipline that is continually engaged late in the cycle. For this reason, APSE includes technical management prominently among the deliverables it includes.

APSE is finished, but not complete. We believe its value would benefit from additional marketing activities, extension to other deliverables, additional software demonstration, and from placement with prominent acquisition forums such as the Defense Acquisition University.

## **2. Introduction**

This is the final report for Air Force Small Business Innovative Research (SBIR) topic AF05-071. The objective of “Embedding Cognitive Systems into Systems Engineering Practice,” was to “develop a process and toolset to embed the application of the emerging practices and technologies of cognitive systems into the traditional practice of systems engineering.” Contract FA8650-06-C-6638, an effort that extended from April, 2006 through December, 2008, was one of three phase II contracts let for Air Force topic AF05-071. The other two contracts were let to Aptima and CHI Systems, Inc. This report refers to the work of these two contractors, but does not report on their activities.

During 2006 and 2007, four hundred fifty man-hours were invested in founding and starting the INCOSE HSIWG. The HSIWG is a mechanism for creating a market for the process and products developed under this, and the other two, contracts. Human systems integration paves the way for acceptance of cognitive engineering into systems engineering processes. The HSIWG activity was not part of our proposed work plan; however, contract dollars were expended to support events that were educational for HSIWG meeting attendees. We incorporated information presented at those seminars into APSE, the product of the extant contract effort. Thus, the contract and noncontract activities, while severable, are intertwined. HSIWG activities are pertinent to this report and are included in its next four sections.

Section 3 describes the methods, assumptions and procedures used in our attempt to infuse systems engineering with human systems engineering and, most particularly, cognitive systems engineering. It describes how we arrived at the product contents and the steps taken to open the market for the required process and toolset.

Section 4 reports on the results of our efforts. It describes the effects of our social engineering attempts to bring multiple disciplines and communities together and the end state as of the contract’s conclusion. It details the features of the APSE product and our success in bringing it to market.

Section 5 provides conclusions, a reflection on our results, the contract scope and the nature of the enduring problem of marrying hard and soft engineering.

Section 6, Recommendations, describes what remains to be done and suggests a road ahead.

### 3. Methods, Assumptions and Procedures

#### 3.1. Overview

“Quite often, I somehow hit a combination of keys that summons a box that says, in effect, ‘This is a Pointless Box. Do You Want It?’ which is followed by another that say ‘Are You *Sure* You Don’t Want the Pointless Box?’ Never mind all that. I have known for a long time that the computer is not my friend.” – Bill Bryson in I’M A STRANGER HERE MYSELF (6).

“The federal government has spent \$195 million on a long-promised wireless radio network for the nation's law enforcement agencies that is at "high risk of failure," the Justice Department's inspector general reported yesterday. Inspector General Glenn A. Fine blamed delays, funding shortfalls and infighting among the Justice, Homeland Security and Treasury departments, whose 81,000 agents are expected to use the \$5 billion system when it is completed by 2021.” – Spencer S. Hsu and Charles Babington, Washington Post, Tuesday, March 27, 2007 (7).

“The set of people who are frustrated every day by badly designed information technology is very large.” – K.J. Vicente, “Crazy Clocks: Counterintuitive Consequences of ‘Intelligent’ Automation.” (8)

“As with many large-scale projects there were many stakeholders to manage both at the project and operational levels. This project was no exception and the contractual arrangement between stakeholder organizations further added to the complication of human factors integration.” – Ian Rowe, “Practical Human Factors Integration, Lessons Learnt from a case study of large project implementation. (9)

“When NCR Corp. asked executives how they deal with the increasing amount of data generated by the corporate world each day, it sounded as though the executives need a life raft. Executives of companies large and small spoke of swimming or drowning in data. Others said they feel frozen, unable to make confident decisions when numbers conflict or take too long to arrive in an understandable form.” – Shannon Joyce Neal, “Today’s executive swims in a sea of numbers.” (10)

“For operations in civil airspace, the term *autonomous civil aircraft* implies the ability to perform all the typical functions required for safe flight while flying in conformance with national airspace constraints, without having a human in the control loop, either on- or off-board.” - Herman A. Rediess, and Sanjay Garg, “Autonomous civil aircraft -- the future of aviation?” (11)



Figure 7: First there was the automobile; then there were passengers (12)

The above examples provide a small sampling of the dissatisfaction, failure, and frustration that result from poor integration of human needs, aptitudes and costs into developing products and their operation. We seem to treat people as in the old Hertz Rental Car advertisements – the system is there and the people are dropped in (figure 7). Resultant costs are high measured in

dollars invested in failed systems, productivity losses in the workplace, and lives lost on the battlefield. This problem is not new.

Phase I research revealed that the problem of including human characteristics, needs, and cost influences within the development, operations and sustainment cycle has been around for between 30 and 50 years. It has probably been around much longer. We assert that the problem arose with the beginning of the industrial revolution when conception and construction of tools became the responsibility of people other than the users of the tools.

When smithies and carpenters crafted their own instruments, tools were designed by their users. Tools were constructed by the artisans themselves to address the needs of their trade. These artisans had the skills to modify, redesign and reconstruct their tools and so articles, like the hammer, evolved to the needs of the tasks they supported. When artisans, such as candle makers, did not have the skills necessary to build their own tools, they had access to the specialists to whom they could relate detailed instructions, in person, for the construction of the gear they needed.

As the scope of tools increased from hand-held tools to compound, powered machines, the fascination with technological novelty began to drive the imaginations of specialists and to wag the tail of product development. When market forces prevail, customer demand reigns in flights of imagination – products that better satisfy needs and tastes survive because they are purchased. Market research is performed to align development investment with customer preference.

When the developer-user relationship is moderated by a purchasing organization or virtual monopoly which restricts customer choice, as in the Bryson example above, the user becomes little more than a ghost. The forces that would drive out innovation for the sake of novelty are absent. People like CIOs decide what users need and their opinions, not user demand, dictate system characteristics. What should be an assessment of functional need, becomes a battle of wills. In the case of IWN, \$195 million was placed at risk.

The need to achieve the integration of human systems integration (HSI) with the acquisition process has intensified with the prominence and ubiquity of software-driven products and systems. NCR executives reported this in the article cited above; it is universal. Autonomous systems can make matters worse. Unintuitive actions taken by automated systems can surprise, confuse and frighten users; when users are required to invoke manual override or implement corrective action, the lack of insight can lead to disaster. This was an issue for the Navy's DDX program which sought manpower reductions through automation.

Investigators for this project set out to retire this enduring and escalating problem. We proposed an aggressive work plan. The work plan was modified dynamically to take advantage of what we learned from our research and identified opportunities. Our policy was to share what we learned, to connect individuals and communities, to educate ourselves in public forums, and to spread the learning as broadly as possible, to give, give, and give some more.

### 3.2. The Work Plan – Beginning and End States

The proposed work plan was integrative. The task names and purpose are given in table 2. Note that software tools are referred to as aids. This is because the term “tools” has a different meaning for cognitive engineers and scientists, to whom a tool is a method or procedure, than it does for systems engineers to whom tools are software products.

Table 2: Proposed Work Plan

#	Title	Purpose
1	Identify Aids that Support An Effective Set of Cognitive Engineering Activities.	Cognitive engineering activities were identified. Software aids that helped in their completion were investigated. A gap analysis was performed.
2	Investigate Commercial Data Management Products	A loosely integrated confederation of software tools was envisioned. Commercial products were investigated to bring the software aids together.
3	Accommodate Acquisition Software Aids	The toolset to embed cognitive engineering was to exchange data with software aids for systems engineering and cost, schedule and risk estimation.
4	Demonstrate Value to Decision Makers	Specialty tools were envisioned to guide the program and project managers and systems engineers to understand when to interact with cognitive engineers and when cognitive engineers were most needed.
5	Software Development	Architecture, features, functions and support to five stakeholders was defined. Plans were made to develop, demonstrate and test the new software.
6	Verification and Validation	This task was to confirm our results.
7	Reporting	We apprised our sponsor stakeholders of our progress and findings.
8	Awareness, Appreciation and Acceptance	This is essential a marketing task designed to move the product into use and satisfy SBIR phase III requirements.

Because we adopted processes that incorporated continuous learning, an approach favored by cognitive engineers, the proposed work plan evolved during the period of performance. Figure 8 shows the way in which the work plan was aligned at the project’s conclusion. Most of the table 2 tasks are recognizable in figure 8, but there is not a one-to-one correspondence. The purposes of some tasks changed, though the titles remained appropriate. Other tasks were merged or transformed. Some tasks were added. The figure shows how the noncontract HSIWG activities fit in to work plans. The reporting task is not shown in figure 8, but was executed.

#### 3.2.1. Overview of Figure 8

The effort divided into three prongs. On the left, we researched and developed the process and tool set. On the right, market development activities are shown. In the center is a bridging activity in which we specifically marketed our product.

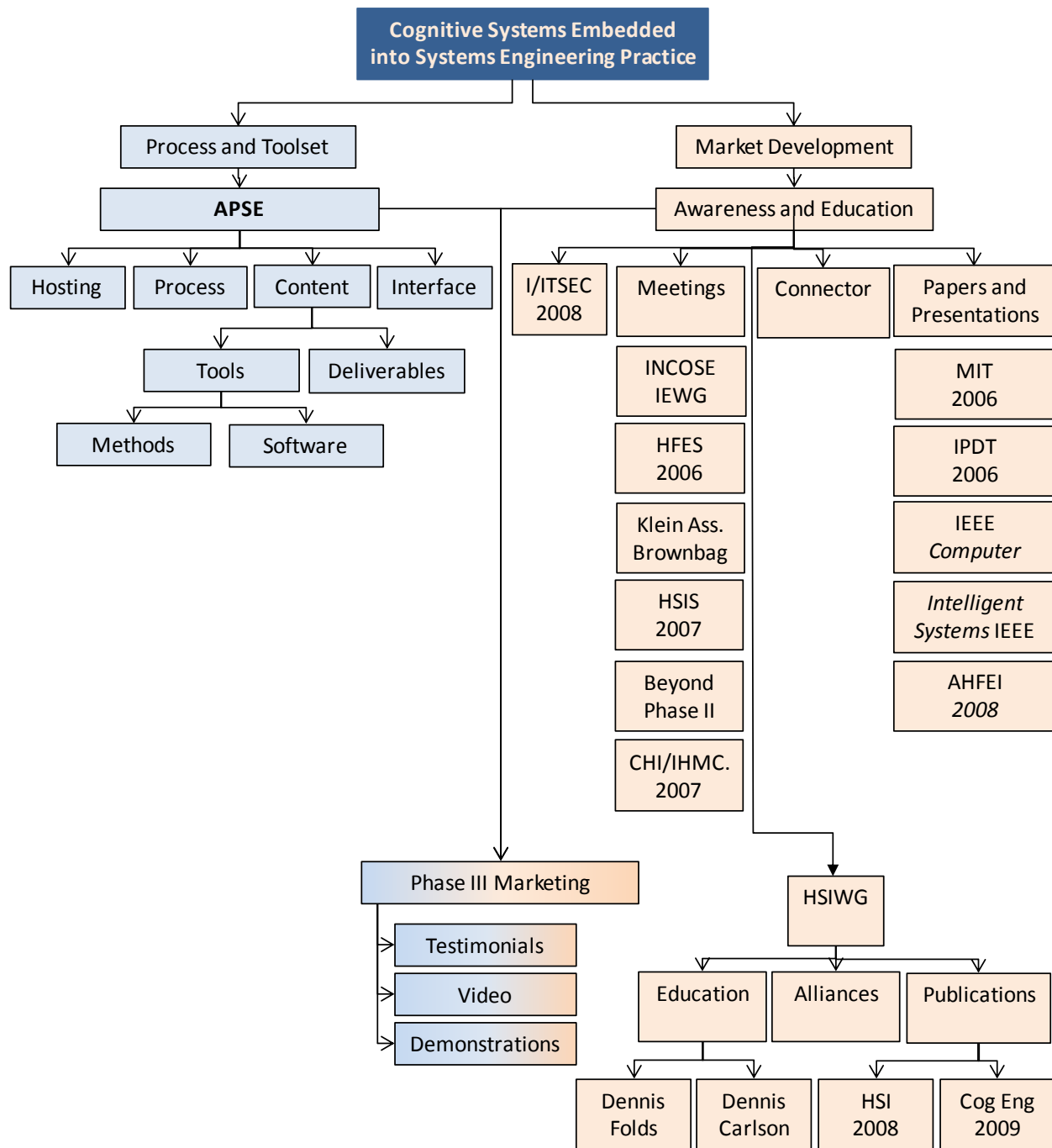


Figure 8: Work plan at project's conclusion

APSE, the toolset, was envisioned as a web-enabled application. Since we wanted the software aid to be acceptable to the widest possible audience, we chose not to brand it with our company name; this shaped our choices of where on the web it should be hosted. Process investigations began with the Defense Acquisition University's Defense Acquisition Guidebook (DAG) and were enhanced by two seminars presented to the HSIWG by Dr. Dennis Folds of Georgia Tech Research Institute (GTRI) (13) (14) and a NATO report Cognitive Analysis, Design and



Evaluation (COADE) (15). Dr. Folds, who described the practice and analyses of HSI in the context of systems engineering, appears at the bottom on the right side of figure 8. Contract-funded research of the COADE report revealed a process that extended Dr. Folds' HSI description to specifically include cognitive engineering. This illustrates the advantages obtained from the complementary contract and noncontract work.

APSE is centered on acquisition process deliverables. A list of over 300 deliverables was compiled. This list was pruned to arrive at the 35 deliverables included in APSE. Descriptive content was generated from investigations of the systems engineering, HSI and cognitive engineering activities, methods and software supports.

A deliverable of the SBIR topic was a toolset. The differing interpretations between cognitive and systems engineering were accommodated by collecting methods, tools of applied psychology, as well as identifying software aids that existed or were required. Cognitive engineering tools, tabulated as part of the phase I effort, informed the APSE population. Software aids were listed and investigated based on provider descriptions of features. We planned to include this list in APSE. However, we determined this approach to be inadequate. Other catalogues of relevant software had been made; these were not found to be useful for people. The only way to really know if a product suits a user's purpose is to try it. So we chose to purchase and exercise select software to demonstrate how it supported cross-disciplinary communications.

In the center of figure 8 are the APSE-specific marketing activities. Phase III marketing was done for APSE in contrast to the market development activities shown on the right side of the figure. Market development encompassed awareness-raising and educational activities that did not feature APSE. APSE was shown in its various prototypes at meetings, when presentations were given and at HSIWG gatherings which are considered part of our market-development effort. The product was sometimes formally presented and sometimes informally shown during breaks or at the end of the day. We gathered use and design inputs from potential users mostly without soliciting them.

Malcolm Gladwell (16) describes a type of person who puts together people with common interests or with solutions to one another's needs as being "connectors." Emily Roth described us as being at the nexus of the cognitive-systems engineering integration efforts. This was done by participating as a vocal proponent at meetings, making mostly invited presentations to forums of professionals. These were all market development activities, opportunities to educate people on the value of HSI and cognitive engineering. In some forums, such as the monthly Project Management International (PMI) meetings, advocacy for systems engineering was required as well.

The HSIWG brought together proponents of HSI and cognitive engineering. It provided the opportunity advance cross-organizational cooperation between the Human Factors and Ergonomics Society (HFES) and IEEE's Systems, Man and Cybernetics Society (SMCS), and the American Society of Safety Engineers. We have already described Dr. Fold's participation in HSIWG meetings. Contract funds also were used to support pitstop design engineer Dennis Carlson's contribution and to purchase reprints of the special HSI-themed edition of *INCOSE Insight* magazine. One hundred copies of this issue were distributed at Wright-Patterson AFB via the Air Force Center for Systems Engineering's Michael Mueller, HSIWG co-chair. Four hundred copies were distributed to exhibitors at I/ITSEC.

The APSE booth at I/ITSEC was the culmination of the project. In addition to demonstrating APSE, passing around the *Insight* copies, and talking with people interested in HSI and cognitive engineering at the booth, vendors were approached to assess their awareness of HSI. We tried to judge the participating training specialists' awareness of their role in HSI and whether they incorporated HSI or cognitive engineering as part of their practice.

Methods used in executing the task items in figure 8 are described in more detail below. First, though, the assumptions that molded the approaches taken are discussed.

### **3.3. Assumptions**

As part of APSE development, assumptions associated with our content were documented. It is very difficult to identify the ground on which you stand while tread upon it. The following describes the position from which we started.

First, we assumed the Air Force was an advocate for embedding cognition. The 2004 Air Force Science Advisory report (17) documented human decision making and performance as critical to air combat, air mobility command, control, communications, computers/intelligence surveillance, and reconnaissance, and information warfare and space operations.

We also assumed cognitive engineering practice was sufficiently mature to contribute positively contribute to improved acquisition outcomes when given the opportunity to participate on an equal footing with other specialty engineering disciplines, e.g., electrical, mechanical, civil, reliability, quality, etc.

As can be seen from table 2, the first assumption was that tools existed and were available to be confederated into a toolset that would align cognitive systems engineering with systems engineering.

We did not set out to fundamentally restructure systems engineering practice or the defense acquisition system. Some of our cognitive engineering colleagues asserted that success would

only be achieved when the old system, and current practitioners, passed away. We did not agree, and did not believe that was a viable stance. Customers depend upon project managers. Project managers depend upon systems engineers for technical planning, coordination and execution. Therefore managers and systems engineers have the authority and resources to engage human systems integrators and cognitive engineers. Even with stories of costly failed systems and user inefficiency piling up, we were unable to conceive of an effective lever that would result in the radically change of existing acquisition processes. We assumed systems engineering success could be enhanced by the contributions of cognitive engineers.

We further assumed the desired process for embedding cognitive systems engineering in systems engineering practice was based upon systems engineering fundamentals. Cognitive engineering's contribution to the acquisition life cycle was to be based on the process described in the DAG.

Our phase I observations revealed there was, at the time of proposal, no viable market for our product. Our plan was to create open source applications, first generation tools, which our target users could use in their practice via the web. As task 8 shows, we felt a large part of the effort was going to be educational – raising the awareness of communities, researchers, and acquisition practitioners. At the inception of our work, there was little appreciation for cognitive engineering and little awareness of what it was and what value it could deliver. This education would take the form of marketing, shown in the right half of figure 8.

We also believed that “not invented here” was a substantial risk to the acceptance of our process and product. We observed rivalries between the services, between researchers, between the disciplines, between companies to be THE ONE who solved the problem. We decided to forgo credit for solving the problem because we believed doing so was essential to actually solving it. Therefore, we chose to avoid branding our product wherever possible. We assumed we could prove the value of our outputs to potential users, and, once proved, they would then use them or adapt them to their own use.

### **3.4. APSE**

Our approach involved exploring the differences between the ways in which cognitive engineers preferred to work and the ways in which systems engineers and traditional project management worked. We incorporated this exploration into project execution.

At the beginning, the project was run along traditional lines. We had a firm schedule with milestones. Subcontracting cognitive engineers rebelled. This was too much of a tops down approach along the lines of, “This is what the solution will look like,” which was determined before any exploration had been done. They felt this was an embodiment of the system that was holding their practice in check. In response, a less-structured, collegial, exploratory approach was adopted to see how it would work.

This worked well at the beginning of the project. It created a more open, exploratory atmosphere in which we identified our five target customers and researched what they were concerned about and listened to their complaints about what didn't work and what needed to be in place. APSE might've been completed earlier if we'd stuck to the original, tops-down approach, but it would've been a different APSE, one that was less responsive to the real problem.

In the final months of the project, cognitive engineers requested that a schedule with milestones be created. Other commitments were pressing on the subcontract team. These pressures left them less free to immerse themselves in this project. Communications became more sporadic; they became dissociated from the activities of the prime contract team. The schedule structure enabled them to plan APSE activities into their schedule which was becoming increasingly crowded. A schedule was put together, but even then, it wasn't as strictly enforced as it would've been for a traditional development project.

The following subsections describe the approaches we took to product and process development. It covers the boxes shown on the left-hand side of figure 8 above.

#### **3.4.1. Hosting**

It was important that the solution to the problem of embedding human engineering, cognition in particular, was not seen as the proprietary work of one company. While there was a definite desire among people in the various communities to solve the problem, to come up with standard processes, procedures, and methodologies that could be called upon, there was also a competitive flavor to dealings as well. Companies, individuals, branches of the DoD, even organizations within the different branches, exhibited type A behavior – each wanted to be the top dog and to have a solution that favored their practice be the one sought. “Not invented here” was a component of the social dynamic that had to be recognized and accommodated.

Additionally, the prime contractor for this effort does not supply cognitive engineering services. If we were to have found THE solution to the problem, it would've put the experts in the cognitive engineering field in a difficult position.

For these reasons, we sought to achieve a community solution. First, we worked to form collaborations. Between phase I and phase II a team of six cognitive engineering and two systems engineering companies crafted a proposal for the Office of Naval Research to collaboratively extend the work we'd been doing in this area. The proposal was not funded, but it did provide a forum in which ideas were shared. Peoples' understandings of the problem changed.

Once phase II awards were announced, a non-disclosure agreement was executed with one of the other awardees. We each sought to sculpt our work plan so that in combination they would

provide greater value to the Air Force. These efforts were unsuccessful primarily due to differing levels of maturity in our plans. Our plan was highly structured which seemed to restrict their flexibility; their plan was more nebulous which made finding a fit difficult.

Our third approach was to take our name off the product. This was a difficult business decision. This being our first contract of substance, we were hoping it would become a springboard to future business. Adopting a posture of anonymity did not support those hopes. Nevertheless, this seemed to be the best value approach for the Air Force, so it was adopted. It turned out to be more difficult than anticipated; the very act of seeking feedback or exchanging information made it our solution rather than the community solution we sought.

APSE was planned to be a web-enabled application. A hosting plan that help people to regard APSE as a community solution was sought. We subcontracted with Wright State University's psychology department. They would perform research and host the product on their web site when it was completed. Unfortunately, this arrangement did not work out in the long term.

Instead, we set out to purchase the URL "apse.com." When it turned out to be unavailable, we instead purchased the URL "acprac.com," and hosted APSE there without branding. It remains to be seen if this approach will be effective. While it does address the not invented here dynamic, it lacks the validity of a known, trusted entity. We wonder if people will be suspicious of the content and so choose not to use APSE. The application has been crafted to capture traffic statistics, so we will be able to tell if people do engage and to what extent they explore the material.

### **3.4.2. Model Process**

Phase I required "a model process for cognitive systems engineering and improvements that would be needed to make the process attractive to government acquisition managers and industry." Phase II required "executable software tools that instantiate the model process in the context of an extension to classical systems engineering."

At the HSIWG meeting at 2007 INCOSE International Workshops, Dr. Jennifer Narkevicius pointed out that HSIWG didn't have the authority to modify documents specifying acquisition processes and procedures. There followed a discussion about the difficulty of making such changes, the lengthy authoring, review and approval cycle, and all of the lower level government and industry processes and tasks that would be affected. Additionally, when the topic of process was raised among systems engineers, a lengthy debate was spawned about process models. The waterfall process was rejected. Incremental processes were preferred. Some advocated spirals. Some advocated fountain- or star-shaped models.

Since our team set as a goal to retire the problem in a constrained period of time, this situation was discouraging. It led us to consider whether the changes to the acquisition process needed to happen in order to instantiate the required changes. As if to confirm our supposition, Robert Machol, in SYSTEMS ENGINEERING HANDBOOK (17) wrote,

***“The steps of system design are logical steps, but they are not performed in order. Logically, one must formulate the problem before one solves it; in fact, one does both simultaneously through the system-design process. Because the problem cannot be adequately formulated until it is well understood, and because it cannot be well understood until it has been more or less solved, the two are inseparable.”***

We explored the DAG and systems engineering processes documented in the INCOSE Systems Engineering Handbook (2), the IEEE Computer Society’s 1220 Standard for Application and Management of the Systems Engineering Process (3) and the Lockheed Martin Space Systems Division Systems Engineering Manual (18). The user-centered spiral developed by Dr. Robert Hoffman (19) was also considered.

From these investigations, we concluded process models might vary, but the in-process deliverables were invariant. Whether a waterfall or spiral was implemented, user requirements still needed to be gathered; functions had to be allocated; specifications and verification plans had to be generated; reviews had to be conducted. This finding was attractive because it removed the burden of process change. If the most important in-process deliverables could be identified, those that had the greatest leverage for embedding HSI and cognitive engineering in systems engineering, then they could be mapped to any process. When the deliverables were generated, how many times and how often would differ, but disciplinary contributions would be the same no matter what the process. As this was an Air Force project, a combined JCIDS and DAS process was selected as the process to which deliverables would be mapped.

Over 300 deliverables were identified from our review of process documentation. The list is provided in Appendix A. This needed to be culled to the most influential for our purposes. Cognitive engineering contributions to the deliverables were documented. A “top ten” list of most valuable cognitive engineering activities was compiled based the experiences of practitioners. The contained those activities they had been called upon most frequently to perform and which had had the most influence on the mission performance. Appendix B contains the list. Table 3 is an excerpt.

Table 3: Excerpt from list of most influential cognitive engineering activities

Integration Points	Methods	Intermediate Products	Deliverables
<b>Field Studies</b>	Cognitive Task Analysis Critical Decision Method Ethnography Surveys Questionnaires Interviews	Cognitive Task Analysis Scenarios Environment Characteristics SKAs Team Dynamics	Early Operational Assessment Operational Assessment Operational Testing Operational Test Agency Report of OT&E Results Sustainment Assessments Post-Deployment Reviews Data Asset Identification User Requirements Functional Requirements HCI Design Specifications TES/TEMP Developmental Test and Evaluation Live Fire Test and Evaluation Test Events Product Support Plan Training Plan Beyond LRIP Report Full Rate Production Decision Review User Reviews Programmatic Environment Safety and Occupational Health Evaluation (PESHE) Support Strategy

The other eight integration points are

2. User Scenarios
3. Walkthroughs
4. Task Analysis
5. User Profiles
6. CONOPS - Navigation Model (high-level view allows navigation through system)
7. CONOPS - Concept Model (development around system's central concept)
8. Training Requirements
9. Feature Definition

The activities are points of integration into the systems engineering process. The table associates methods and intermediate products. In the final column, deliverables from the list of 300 are associated with the integration point as shown in the second column of figure 9 which illustrates the process used to reduce the 300 deliverables to the final 35 that were incorporated in APSE. Acronyms used as abbreviations in column 2 are expanded in the List of Symbols, Abbreviations and Acronyms in the back sections of this report.

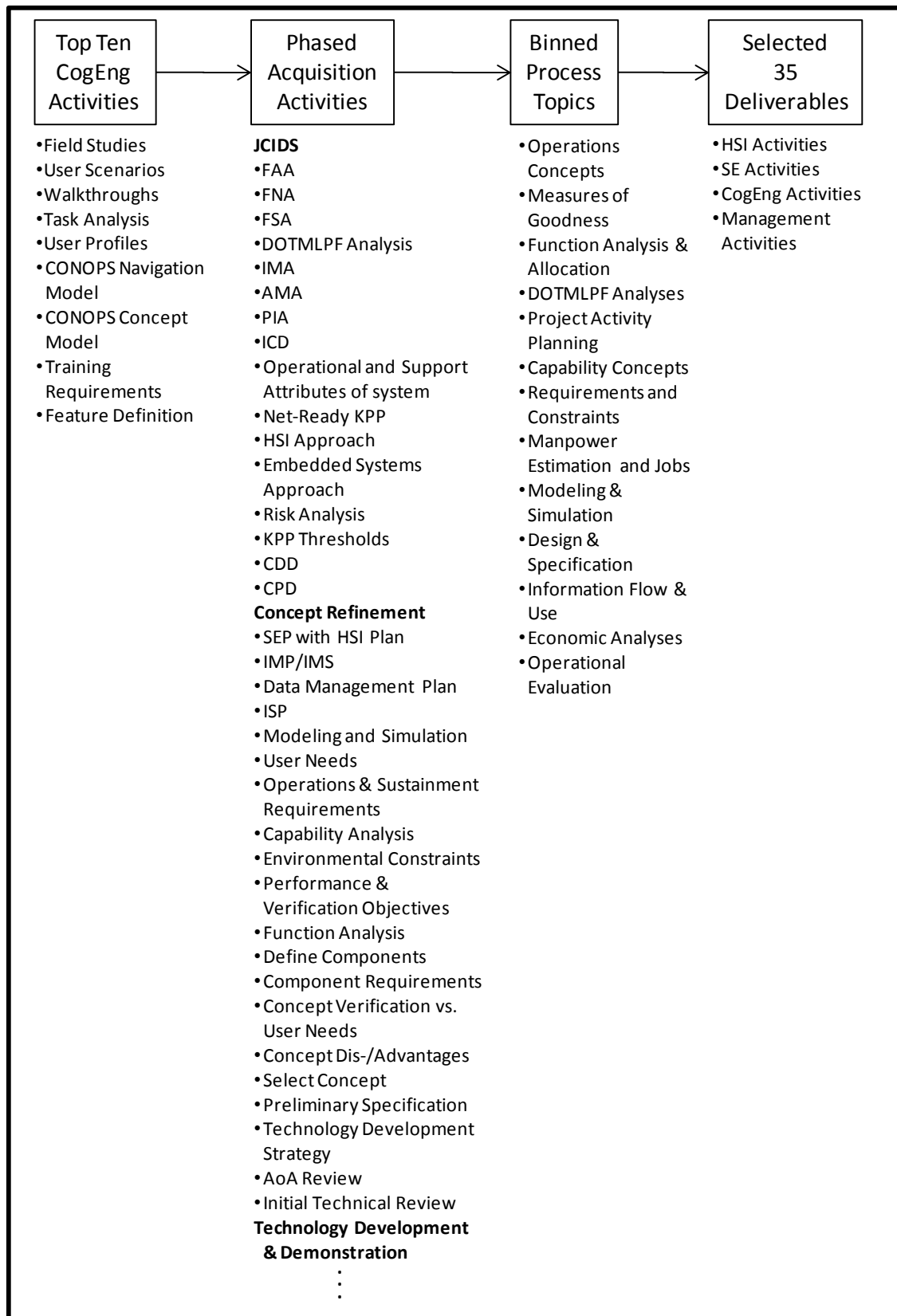


Figure 9: Reducing from 300 to 35 APSE deliverables



Themes were identified from the phased list which allowed us to identify process topics to be addressed in APSE. The third column shows the 13 categories that evolved. Fifty-six in-process deliverables were identified as the most relevant to these categories. Duplicates were identified which reduced the number to 50. HSI, cognitive engineering, systems engineering and project management activities were mapped into the categories. This enabled us to prioritize the 50 remaining deliverables, and place them in the appropriate phases.

We have described how the cognitive engineering activities were arrived at. Systems engineering activities were taken from manuals and handbooks and the author's experience. Project management activities are described in the DAG. The HSI activities were taken from a presentations covering HSI analysis given by GTRI's Dr. Dennis Folds.

Dr. Dennis Folds of Georgia Tech Research Institute presented "Human Systems Integration" at the June, 2007 HSIWG meeting. Figure 10 is a slide from that presentation. Dr. Folds subsequently presented a half-day seminar on HSI Analysis at the January, 2008 HSIWG meeting. Those slides are downloadable from within APSE.

## Mission Task Analysis in Design

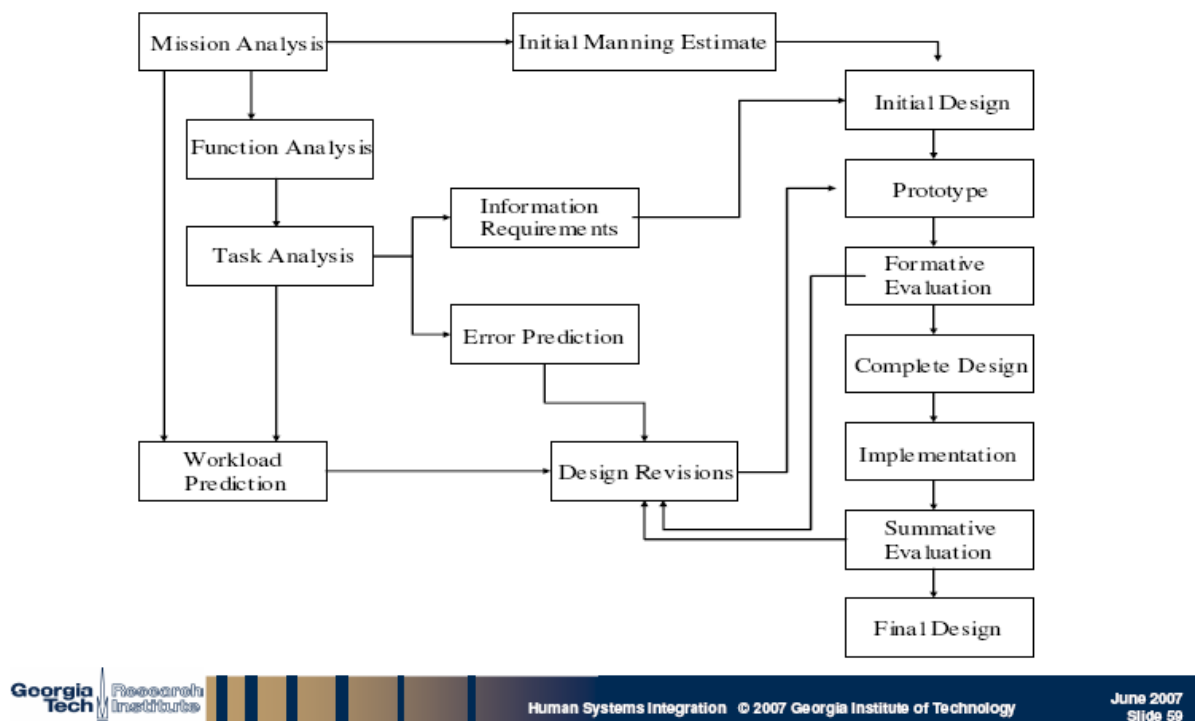


Figure 10: HSI Analyses per Dr. Dennis Folds (13)

Shortly after Dr. Folds' presentation, we reviewed the NATO COADE (15) report. The COADE study offered the model process for cognitive engineering analysis and design that is depicted in figure 11. Note that the figure-10 mission analysis, function analysis, and task analysis matches

those in the first line of the COADE process. Dr. Folds' description of task analysis matches with the COADE behavior task analysis.

By comparing figures 10 and 11, it can be seen that HSI analyses provide inputs into cognitive engineering analyses. Since cognitive engineering is a component of HSI, some of the HSI analyses are actually performed or supported by cognitive engineering methods. For example, cognitive engineering supports HSI manning estimates, information requirements definition, and error prediction.

Storyboards were constructed to connect the process and products of JCIDS and the DAS with those of the HSI and COADE analysis processes and with the activities that were documented in the phase I flowcharts. In doing so, we confirmed that HSI and cognitive engineering could be included in the combined JCIDS/DAS process without requiring its revision. In addition, this allowed us to complete the process shown in figure 9 which reduced the 50 deliverables to the 35 included in APSE.

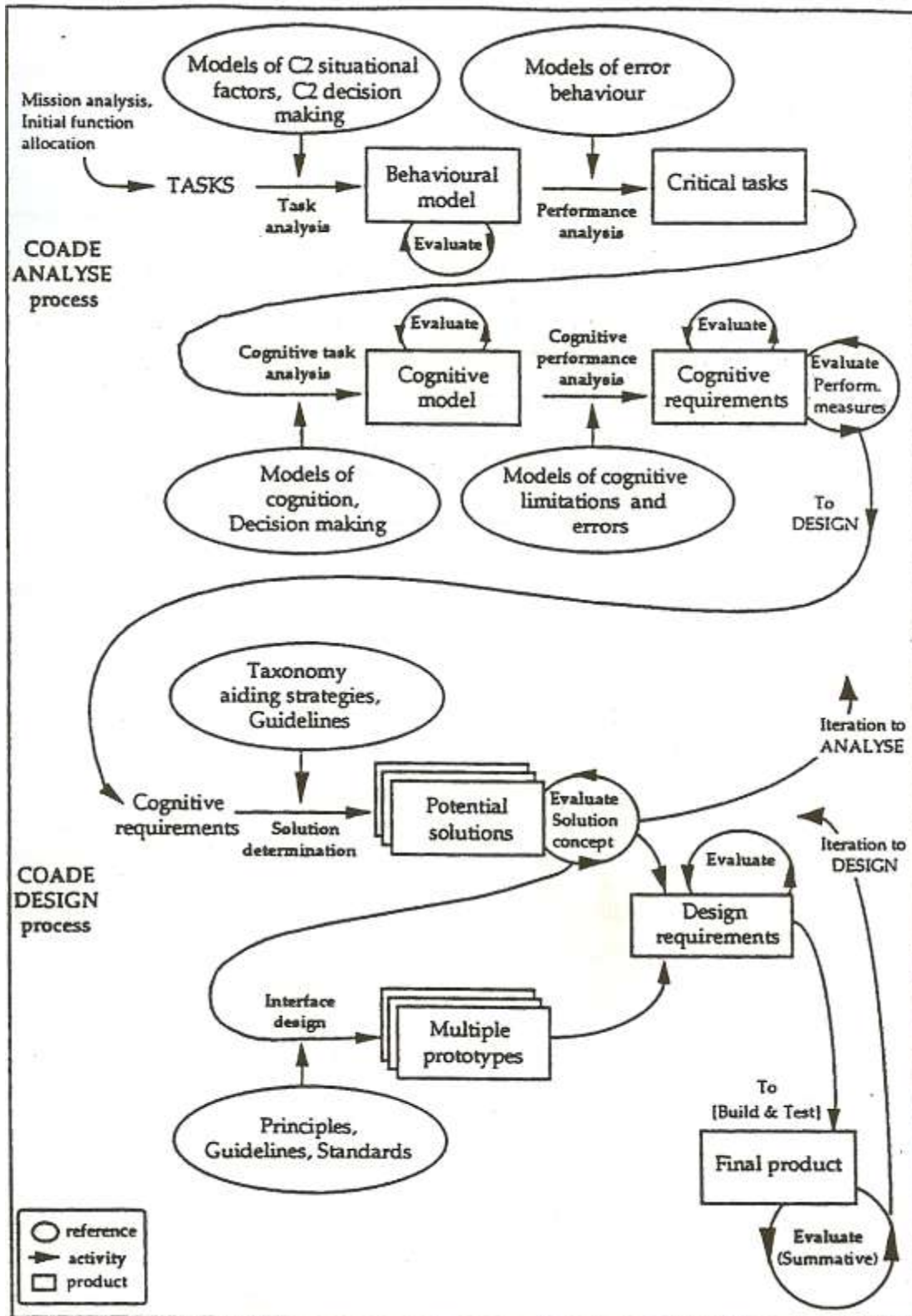


Figure 11: COADE Model of Cognitively-centered System Design

### **3.4.3. Interface**

For some time process analysis, deliverable definition and content generation subsumed the entire effort. The cognitive engineering members of our team began to have trouble conceiving the evolving product and insisted that some attention be paid to the user interface. A series of prototypes was generated. Informal feedback was provided by potential users including members of the design team. The evolution of the APSE main page is provided in Appendix C.

The first version of APSE was created using the Backpack web 2.0 tool by 37 signals (20). It was primarily repository for content at the time when the Backpack deliverables list contained 150 items. Backpack poorly aggregated related content. Descriptions were separated from supporting graphics, documents and files. It was difficult to edit and format text. Each page had separate permissions which were difficult to manage. Backpack did have collaboration tools such as texting and chat that would've been advantageous if APSE had become the collaborative design tool it was originally envisioned to be.

It seemed wise to use a cognitive engineering product to communicate the benefits of the discipline. A concept map version of the main page was devised. It is shown in figure 12. Many of the functions of the final product can be seen in this view. The blue ovals contain the featured content – deliverables, methods and software. At that time, we considered incorporating high value activities as one of the functions. Once we slimmed down to 35 deliverables, however, all the content was considered to be high value and this feature was dropped.

The concept map version was not favorably reviewed. Surprisingly, the negative comments came from a proponent of concept maps. This person felt the map was useful, but was not appropriate for the main page. It did not lead users through the material and made action steps difficult to discern. Enhancements in the form of process bars and links to high value activities were added, but the design was not acceptable. Subsequently, an input/output version and a tabbed version were developed. The design team didn't feel these provided the desired look either.

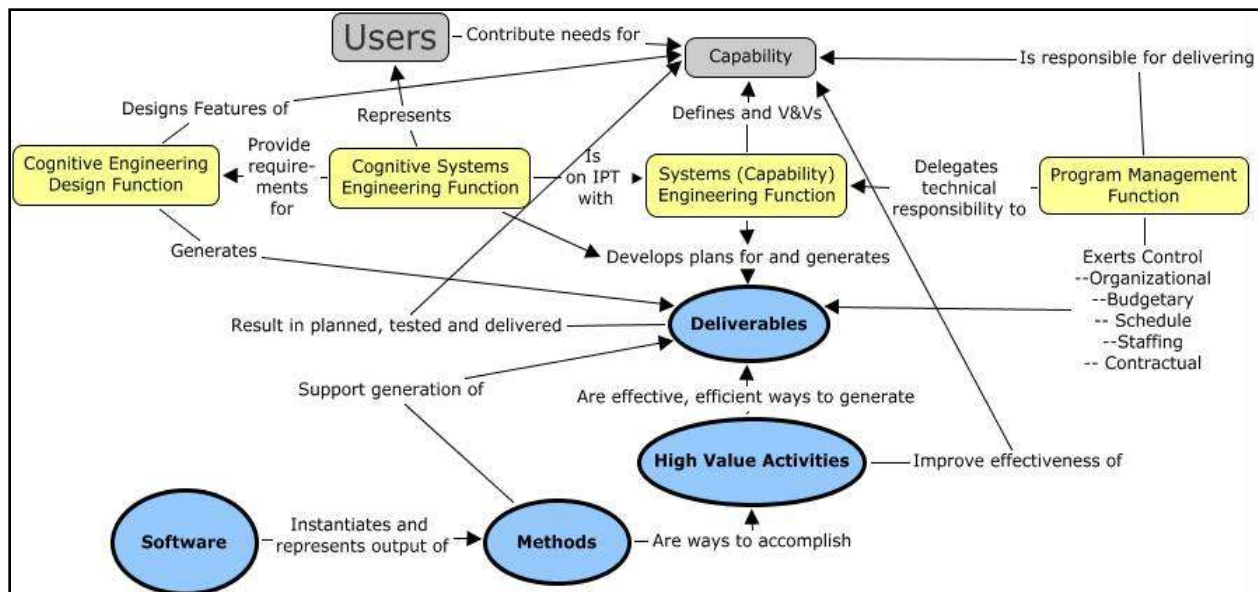
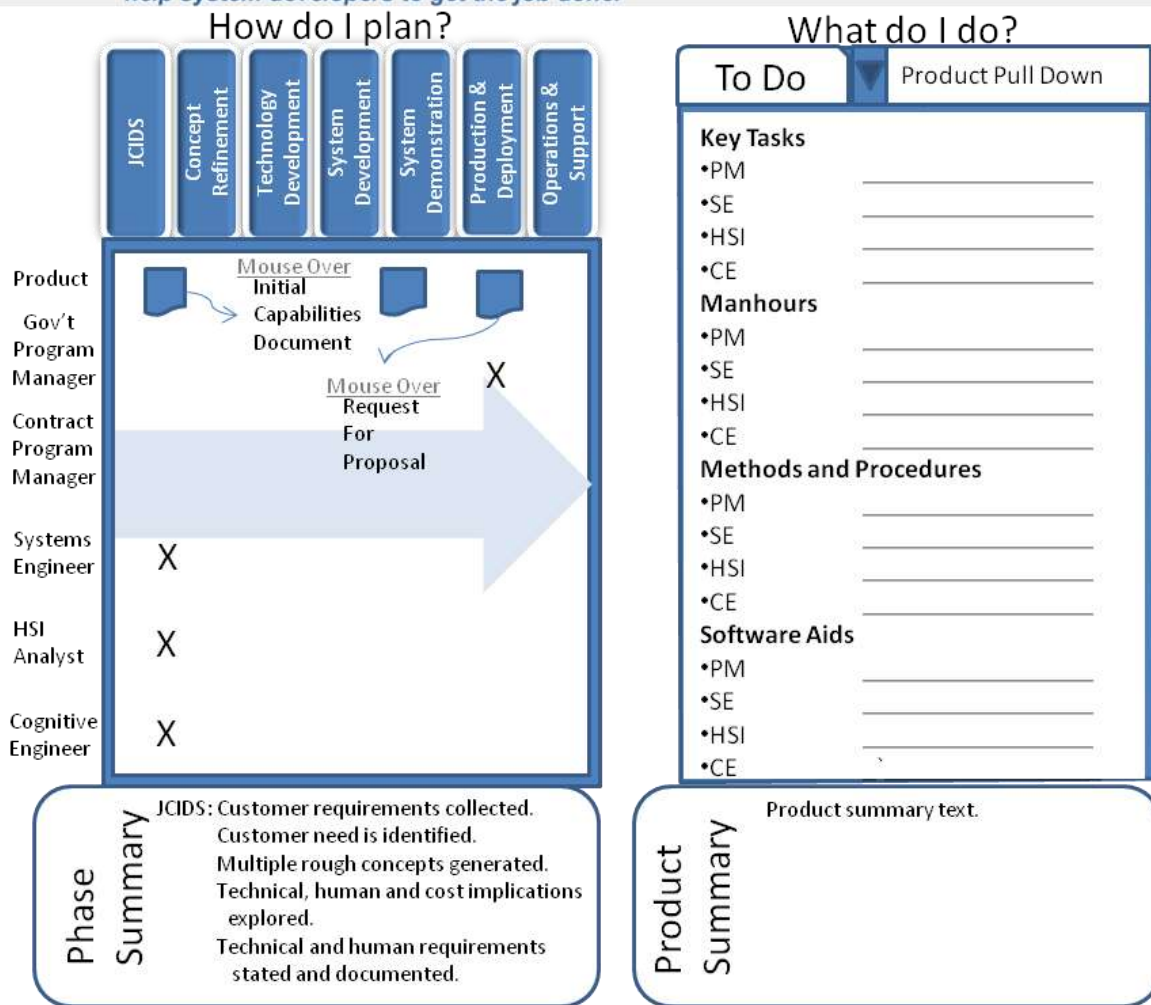
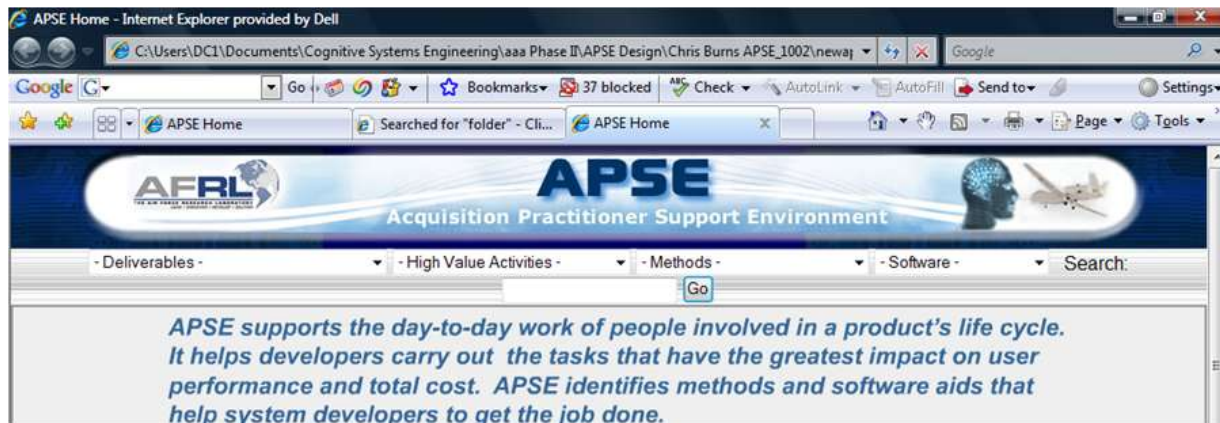


Figure 12: Concept Map for APSE Front Page

Knowing that APSE would be a “tough sell,” a dynamic, attractive, fun-to-use interface was sought. We looked for novelty that would attract users along with functionality that would be useable and useful. “Best of breed” web interfaces were explored. These were found by performing internet searches on award winning web sites. Web sites of museums, which were attractive and fun, were favored. Two dynamic and attractive sites were <http://www.brainpop.com/>, and <http://xplane.com/#/problems/>. They contained a lot of content and were engaging, and served to set our expectations for an acceptable APSE design.

We created storyboards of potential main and deliverables pages using Microsoft PowerPoint. Cognitive walkthroughs of the storyboards were conducted. These were used to assure that the interface would guide users to execute the actions we wanted them to. For example, a win for us if the project manager took away the following: 1) When to include cognitive engineers and HSI personnel in planning; 2) How to discriminate between subcontractor offerings; 3) An understanding of what contributions to expect from cognitive engineering and HSI practitioners. After internal discussion, a mockup was shown to Dr. Fran Greene of the Air Force HSI Office. Dr. Greene mentally translated our message and described a new interface which is shown in figure 13.



## Our Story



What will give me highest return on assets employed?

Figure 13: APSE main page mockup post Dr. Greene feedback



The panels in the center reflect Dr. Greene’s descriptions. On the left is “what do I do?” On the right is “how do I do it?” The design is still static and not very interesting, but the functionality is very close to that of the final product.

Discussions among the design team revealed a shortfall in the cognitive engineering process that is shown in figure 14. Engineers, in the applied science process, have a systems-design-production/manufacture progression. Interpretation between the production function and design function is provided by the core systems engineering team. Cognitive engineers, in the applied psychology process, lack the design function. In the absence of cognitive engineering participation, user interfaces are developed by software engineers or web developers who are not trained or equipped to develop intuitive and effective interfaces, particularly for mission critical functions. A specialist in human-computer interface (HCI) design is sometimes called upon to fill this void, but the role is not institutionalized. For commercial web interfaces, that function is filled by a graphic design. Subsequent to this conversation, a graphic designer was added to our team. The designer, working from figure 13, created a flowing, artistic theme.

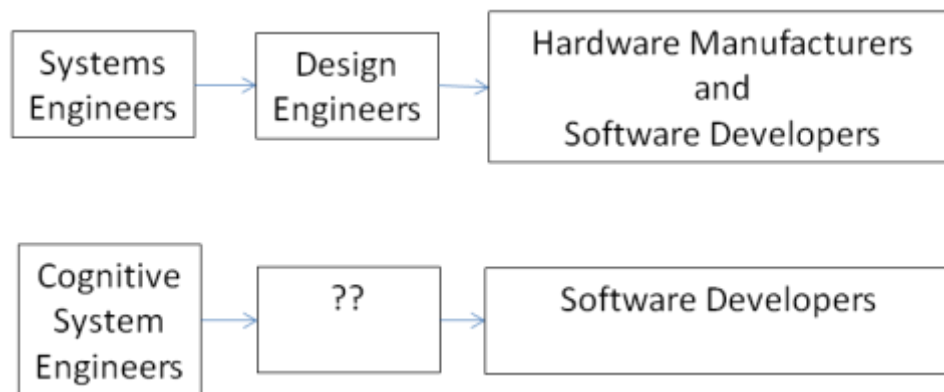


Figure 14: Design function missing

After the visual design was complete, it was turned over to a software engineer who added dynamic windowing and graphics. This resulted in the desired interesting and functional design we had been seeking.

#### 3.4.4. Content

The concept of a loose confederation of analysis tools was proposed. APSE wound up as a planning tool with many of the elements of an e-learning system. How did this transformation occur?

First we noted that the software needed to instantiate the phase I model process. Figure 15 aggregates the attributes of that process. The content in figure 15 does not describe a confederation of analysis tools. It looks like a project planning and management tool.



Figure 15: Activities flow-charted in phase I provided initial content for APSE prototype

Next, we found out more about the disposition of the US Navy’s Human Centered Design Environment (HCDE) created which had been explored in phase I. While the NAVSEA has not maintained use of the HCDE in the Navy Capability Development Process, it has retained Interchange SE. The demise of HCDE gave us pause. NAVSEA had developed a fairly capable analysis capability which, by reports, still some needed work and then ceased to fund it.

Finally, there was the question of users. Systems engineers at HSIWG meetings were asking, “What is cognitive engineering anyway?” “Where can I find out more?” Only a small subset of the systems engineers knew what HSI was. At PMI chapter meetings, the author questioned attendees to determine their awareness of HSI and found none, so it was not on the management radar screen either.

At the Integrated Design and Process Technology 9th World Conference in June, self-styled systematist Jack Ring said off-handedly, “Systems Engineering artifacts are e-learning products for Engineering.” This led to modification of the APSE concept. They were expressed as the following postulates, corollaries and elaborations.

- Postulate 1: APSE is essentially an e-Learning tool.
  - Structure APSE around life-cycle deliverables taken from systems engineering manuals and the DAG.



- Appears that Systems Engineering Plan (SEP) may provide a backbone for the e-learning environment.
- Postulate 2: APSE must provide valuable functionality that draws seasoned users into the e-learning experience.
- Corollary 1: APSE must not require user activity that is not perceived as value-added that would be routinely by-passed.
  - Provide users with new material.
  - Provide users with reference material.
  - Provide users with software aids.
- Postulate 3: Organizations, the various systems engineering standards, senior practitioners each have their own process model consisting of the logical systems design steps.
- Postulate 4: It is not so important to instantiate a process but to support the activities that go into executing the logical steps.
- Postulate 5: APSE will support key activities that need to be accomplished in a system's life and help users to understand when it is appropriate to execute those activities.
- Corollary 2: APSE will not attempt to define a single, definitive process.
  - APSE is a structure of supported activities identified in phase I centered on the products (hardware, software, planning, design, sustainment artifacts) that must be generated for a system during its lifecycle.
  - However, for novices, an exemplary framework is required in order to put the APSE deliverables in content.

The architecture was refocused from being primarily a loose confederation of software to a work aid that had a deliverable focus. Details for deliverable generation were co-located within a web-enabled software application. Information about deliverable preparation was broken into several pages -- a summary page and a detail page.

At the time the postulates were formulated, the software confederations had not been abandoned. A freeware version of the confederation, called a Simple, or Study, Project, would be available by means of the APSE application. Recommendations would be made for a Professional Project analysis architecture which would require separate purchases of contributing software by the organization or individual using APSE. Figure 16 lists the features of the revised APSE concept.

- Plan a project
  - e-Learning tool to guide managers, project planners and students through setting up a project.
- Start a simple project
  - Users employ the freeware version of APSE in conjunction with “Plan a Project” to initiate a project.
- Start a professional project
  - Users are provided guides in selection and setting up a project incorporating professional-caliber aids.
  - Work captured in the “Simple Project” environment is subsumed by the professional database.
- Work on existing project
  - Log in and continue work on an existing project.
- Manage project workspace
  - Global APSE administration function
- Manage personal workspace
  - Allows users to tailor APSE to their personal preferences

Figure 16: Features of APSE e-learning concept

The workspaces were subsequently eliminated from the concept due to software considerations that will be described in the Software section, below.

There are many handbooks, guidebooks, standards and policies that guide acquisition practice. For example, the DAG lays out the entire acquisition process. It is a massive and impressive work. Why would people go to APSE instead? Leaning on recent work performed for DARPA on the topic of rapid and accurate information transfer, we found that these massive, impressive handbooks are rarely accessed. During our first time through the DAG, typographical errors and dropped links were caught, listed and sent to the DAG webmaster. He was delighted to get the updates, but even more to hear that someone had actually used the document!

We find that people don't have time to read the complete, detailed documents that describe in excruciating detail. They are looking for information they need just-in-time. The internet has set their expectations. They can perform a search and have information needed instantaneously. True, they could upload a standards document and search for a desired topic, but even then, it is not presented in actionable form.

Standards and manuals are generally at too high a level for actual practice. The Lockheed SSD we reviewed is an exception to that. It is a cookbook for the systems engineering process providing step-by-step descriptions of activities as well as the forms required to complete tasks.

APSE is designed to provide the just-in-time information people require. Not only that, it is sparsely populated. By that we mean that few words are used to delimit the deliverable being treated. Text fields were purposely kept short. The temptation to shrink white space in the graphic design was ignored. Our goal was to make it possible to obtain a conversational understanding at a glance. The architecture then provided succinct materials for going deeper into the subject as required to satisfy the APSE user's need.

APSE does not dismiss, replace or replicate existing information repositories. Hyperlinks to relevant DAG pages and detailed descriptions of cognitive engineering methods on the MITRE Mental Models web site (21), for example, were incorporated into APSE. When representative support software is listed, links to the vendor web sites were included.

Templates that directly help a person to complete a specific deliverable or support product were also included. These are another example of the just-in-time information provided by APSE. Table 4 provides an example of the Decision Requirements Table developed by Klein et al. (22) that is included with the Task Analysis deliverable. The document is provided in downloadable Microsoft Word format so users don't even need to create it for themselves.

Table 4: Klein et al. Decision Requirements Table Example

<b>What is the difficult decision?</b>	<b>Why is it difficult?</b>	<b>How is the decision made?</b>	<b>Recommend Human Computer Interface aid. Identify how will it help?</b>	<b>Decision Frequency</b>	<b>Number of Decision Incidents</b>
Discriminating vehicles from tracks.	Operator must discriminate non-combatants from adversaries before making engage recommendation.	Operator relies on software translation of hyperspectral imagery to match sensor returns to a priori vehicle types.	Improve a priori typing and provide correlation certainty (ambiguity) indicator.	12	7

As a final note on content, APSE should ideally be a collaborative tool that receives contributions, updates and fosters debate within the community. We have, for the moment, abandoned the notion of APSE as a tool to which community members can contribute. After some exploration, we found no way incentivize users to contribute content to APSE. We could see people loading research papers and general information into a repository, but details of their day-to-day practice are proprietarily guarded. Extensive uploads of generation information would have created a daunting information repository with all of the detriments of and none of the benefits of the DAG's organization.

#### **3.4.4.1. Deliverables**

APSE content was centered on deliverables and descriptions of the tasks, manhours, methods and software aids that support deliverable development. We have not included all in-process deliverables in APSE. Section 3.4.2 describes the process that was used to select the 35 deliverables that are the centerpiece of APSE. Essentially deliverables were selected because of their value in moving cognitive engineering into the process and cognitive attributes into systems.

The generated list of deliverables was biased toward technical products, such as requirements, simulations and analyses. That is because these were the products that cognitive engineers have historically been asked to contribute. This bias has limited their practice. For example, Dr. Kelly Neville pointed out during phase I discussions that cognitive engineers were brought on late in the development cycle. When changes to user interfaces were recommended, software engineers pushed back claiming this to be requirements creep. Requirements creep is always a bad thing. It is costly. It is disruptive. Dr. Neville felt her contributions were at the mercy of software engineers and generally were not adopted.

Systems engineers recognize that requirements do change during development. True, it becomes more difficult to do this as the product matures because of cascading effects to interrelated subsystems, but systems engineers, as a matter of course, adjust requirements when performance shortfalls are found in test in order to rebalance the system. Rebalancing assures that the delivered system still meets mission requirements.

There is a process for requirements change of which Dr. Neville was not aware, that is the configuration management process executed by the configuration control board (CCB). It is a technical management process that was left off the original, reduced set of deliverables. Many technical management deliverables replaced purely technical deliverables in the set because they were enablers for cognitive engineering practice.

#### **3.4.4.2. Tools**

Lack of a common lexicon is one of the barriers to cognitive engineering and human systems integration practice. The word “tools” encompasses a topic on which a systems engineer and cognitive engineer can have a lengthy discussion without ever realizing that they are speaking of two entirely different things.

The HSIWG identified this challenge during its formative days (23). There are three areas where confusion arises. First, the same word can be used to mean two different things. Second, different words can be used to name the same thing. Third, people are unfamiliar with terms used by practitioners of other disciplines; this becomes especially damaging to integrated practice when people don’t seek clarification.

Many cognitive engineering practitioners come from research backgrounds where tools refer to questionnaires or analysis methods; their training does not customarily include computer programming. On the other hand, engineers cut their teeth on programming. Computers and software that run then are their tools. The question of whether cognitive engineers should be trained to write software and develop user interfaces was raised several times during the period of performance.

#### **3.4.4.2.1. Methods**

Identifying related methods was one of the tasks of deliverable content population. This is important because it addresses the third lexical challenge – practitioners from other disciplines who do not know the meaning of terms used by others. Systems engineers were observed closely at one of the INCOSE symposia. Instances when new terminology was introduced were particularly noted. Those observed who found themselves faced within unfamiliar terminology preferred to bluff their way through the conversation rather than admit they didn't know. The author observed this frequently when attending classes at MIT. Very intelligent, competitive students didn't want to show weakness by admitting ignorance. Questions were rarely asked in public.

Systems engineers and project managers are unfamiliar with cognitive engineering and HSI methods. Sometimes they may have heard the term, but not had the time to investigate its meaning. Or perhaps the term wasn't relevant to the work they were currently doing. This leads to situations that cognitive engineers experienced on DDX. The systems engineers welcomed them, said they could really use the cognitive engineer's help, and next asked, "What do you do?"

Project plans, sections of requests for proposal and other guidance documents require that interacting practitioners understand the terminology of the HSI and cognitive engineering. If authors of these documents are unaware of the meaning of the terms, confusing or misleading text is the result. When reviewers, such as a project manager see things they don't understand on the integrated master plan, they are apt to redline them. Unfamiliarity with methods can lead cost reviewers to question the line item. Ultimately a rudimentary understanding of applicable methods is important to embedding cognitive engineering in acquisition practice.

A table of cognitive engineering methods was developed in phase I. The table associated methods with activities that were captured on phase I flow charts that described cognitive engineering contributions to systems engineering products. These were, in part, used to populate the cognitive engineering methods sections of the deliverables pages.

Methods were also called out in the “top 10” list generated by the project’s cognitive engineering subcontractor. They are listed in table 5. The table 5 methods were preferentially selected over those developed in phase I because of the empirical backing they had in comparison to the document research used to generate the phase I table.

Table 5: Methods from “top 10” list

Artifact Study Behavioral Task Analysis Cognitive Task Analyses <ul style="list-style-type: none"> <li>• ACTA</li> <li>• ACWA</li> <li>• COGNET</li> <li>• Cognitive Function Modeling</li> <li>• Cognitively Oriented Task Analysis</li> <li>• Comprehensive vs. Focused CTA</li> <li>• Concept Mapping</li> <li>• Contextual Control Model</li> <li>• COSIMO</li> <li>• Course of Action Analysis</li> <li>• Critical Decision Methods</li> <li>• Decision Ladder</li> <li>• Decompose, Network and Assess (DNA) Method</li> <li>• Empirical Framework</li> <li>• Focused CTA</li> <li>• Goal-Directed Task Analysis</li> <li>• GOMS</li> <li>• Grammar Techniques</li> <li>• Hierarchical Task Analysis</li> <li>• Hi-Lo</li> <li>• Interacting Cognitive Subsystems Analysis</li> <li>• KADS</li> <li>• PARI</li> <li>• RPD</li> <li>• Semiotic Models</li> </ul>	<ul style="list-style-type: none"> <li>• Skill-Based CTA</li> <li>• Sub-Goal Template</li> <li>• Task Analysis for Error Identification</li> <li>• Task Knowledge Structures</li> <li>• Tasks Analysis for Knowledge Description</li> <li>• Team CTA Techniques</li> <li>• Verbal Protocol Analysis</li> </ul> Contextual Design (Work, Flow, Cultural, Sequence, Physical, And Artifact Models) <ul style="list-style-type: none"> <li>• Interviewing Techniques</li> </ul> Contextual Inquiry Cognitive Work Analysis Ethnography Information/Data Flow Review Instructional System Design Interviews Micro Saint Simulation Modeling Naturalistic Decision Making Qualitative Trade Studies Questionnaires Scenario Review Simulation Situation Awareness Oriented Design Stop-Action Scenarios Surveys Time-Motion Studies What ifting?
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There are many repositories of cognitive engineering methods in books, in journal articles and on the web. The most accessible is MITRE’s Mental Models web site (21). We planned to introduce links to the MITRE site, because it provides the seminal references for the methods. One shortfall of the method literature is that collections are targeted at cognitive engineering practitioners and are difficult for people without an applied psychology to understand. Additionally, method descriptions are not neutral; authors usually have an agenda to promote

their preferred “school” or “method” over others. This is confusing to systems engineers and project managers who sincerely wish to include cognition in system development and operation. Systems engineers and project managers don’t know who to believe or where to turn to obtain the help they need. Everyone sounds like an authority.

Succinct, 20-word-or-less descriptions of the methods are required for systems engineers and project managers. It was our plan to generate these, but they have not been completed as of this writing.

Our team found that it was easier to ascribe and describe methods of other practitioners to the deliverables as opposed to our own. The author is a systems engineer. Because the systems engineering methods were so ingrained, taken for granted, it was difficult to put a name to what was being used to support a deliverable. On the other hand, the cognitive engineering colleagues were readily able to identify the omission of relevant systems engineering methods from associated deliverables.

We also examined development approaches, philosophies, that were in keeping with the ways in which cognitive engineers worked. For example, one attribute of cognitive engineering procedures that superficially appears to be at odds with traditional project management is continuous learning throughout the development cycle. In a continuous learning environment the project must continually adjust and refine its offering as new information is garnered. We explored techniques that seem suited to this paradigm -- Set-Based Concurrent Engineering, Rapid Software Development and Integrated Modular [software] Architecture. Our research showed these techniques fit well in both the systems engineering and cognitive engineering models. The techniques must be implemented by an enterprise through program or project management. It was a weakness of the final APSE design that our research on these techniques found no place in the architecture.

There were also approaches that came out of the systems engineering world that are not institutionalized in its practice. For example, Dr. John Warfield, who for 50 years has been working to better incorporate human needs, developed the Interactive Management methodology and Interpretive Structure Modeling software along with his colleague Dr. Alexander N. Christakis (24). Christakis has documented the derivative structure design process (SDP) also called the CogniScope Approach. CogniScope also employs software, CogniSystem.

The purpose of the work of Warfield and Christakis is to lead stakeholders through process that identifies needs and the root causes of those needs to that a logical action plan can result. These techniques provide a bridge between systems engineering and cognitive engineering knowledge elicitation. They are comprehensive, but can be time consuming and so are underused to the detriment of system development. They are highly relevant to the JCIDS process, so we have

incorporated references to the work of Warfield and Christakis in JCIDS deliverable descriptions.

Quality Function Deployment (QFD) is another comprehensive, time consuming technique that is effective during concept development and refinement. It, too, is underutilized. A simplified version of QFD was developed for the capstone design course in space systems engineering at University of Illinois' Urbana campus. A cookbook with examples was prepared to walk users through the technique. Templates and references have been included in JCIDS documentation.

An emphasis was placed on methods to support JCIDS, where gaps are identified and concepts are developed. If human contributions to a functional solution are incorporated at this early stage of development, then DOTMLPF analyses will be more complete and solutions will incorporate people in ways that enhance the mission without unnecessarily driving up operations and sustainment costs. We demonstrated the strong correlation between DOTMLPF and HSI in a presentation made to the local chapter of INCOSE. Aside from the materiel component, DOTMLPF is all about how people are managed, organized, trained, educated, selected and accommodated. These are all topics treated by HSI.

In the course of exercising the DeSAT and SuperSAGAT software tools by SA Technologies, it was necessary for us to simulate a Goal-Directed Task Analysis. GDTA was researched and an example was generated. The GDTA process resulted in situation awareness requirements, though the requirements were not in a form usable by engineers. We used the INCOSE Requirements Working Group's draft *Requirements Writing Guide* (25) and translated GDTA-style requirements into actionable "shall statements" to demonstrate the connection between cognitive engineering and systems engineering. The GDTA example, with the requirements translation tables, was an unplanned artifact. We need to identify how it fits in the APSE architecture. Once we do, it will be incorporated as an example.

#### **3.4.4.2.2. Software**

For both the freeware and professional confederations of analysis tools, we researched software aids that could be used as data repositories and project management, systems engineering, human systems integration and cognitive engineering analyses. On-line research was performed and literature was reviewed for applicable software.

We discovered a number of freeware tools that were appropriate. Many were no longer supported. We discovered tools that were the subject of research and development projects. We were unable to obtain some of those from their developers; others did not have a commercial license agreement that would make it possible to recommend them to users who were not researchers or college students. Software vendors, including cognitive engineering houses, touted aids on their web sites that seemed relevant to the professional project. A list of the relevant software that was uncovered is in Appendix D.



We had planned to include a listing of applicable and available software in support of building integrated design environments. We found that such a list provides little or no value to users. We discovered four repositories of HSI/cognitive engineering software tools in web, document and database form and consulted the extensive web-based INCOSE System Architecture Tools Survey. The following two on-line repositories no-longer exist: 1) Navy Human Performance Center; 2) National Defence and the Canadian Forces. DTIC maintains the Directory of Design Support Methods (26) which holds human engineering tools. AFRL conducted a survey of NAVSEA HSI software (27) that describes 52 software aids.

At the June 2007 HSIWG meeting, the author posed the question, “Have any of these repositories helped to advance the practice.” After stunned silence, there was an admission that they don’t appear to have helped. The repositories, like the guidebooks and manuals are too unwieldy to use and too voluminous to read. Tool descriptions don’t seem to help users to target value applications.

This finding led us to change our approach to the software. We selected tools with functionality that builds bridges between cognitive engineering and systems engineering practice and exercised them in examples, documented the steps it took to build a model or a use the software, and provided our experience in working with the product for users.

The time spent on each step was recorded. Software prices were billed using the ranges shown in figure 17. Recording the time used to set up the exercise the software along with its retail price enables project managers to budget for its use.

Freeware/share (\$0)
< \$100
\$100 - \$500
\$500 - \$1,000
\$1,000 - \$5,000
\$5,000 - \$10,000
> \$10,000

Figure 17: Software price ranges

Software demonstrated in this narrative fashion, including examples of input and output work products provides a perspective user with the information required to determine whether it is applicable to the job they have at hand. The stories illustrate how the tools provide information that can be used by all of the APSE target users.

Demonstrating software is more expensive and time consuming than creating a listing or repository, so fewer examples were included in APSE than were desired. We exercised the software listed in table 6.

Three of the tools do not appear in the APSE product. CMap Tools is a useful means of capturing data that could serve all project stakeholders. It was used to construct the prototype main pages, shown in the Interface section above. It was not included among our software demonstrations.

Table 6: Software exercised

Software	Value to APSE users	Notes
CMap Tools	Organization of project information; could be part of data repository	Not included in APSE demonstrations. Used for prototype main pages.
Micro Saint Sharp	The 2-D and 3-D modeling and simulation capabilities are representations that can be appreciated by systems engineers, project managers, and designers.	
Task Architect	Task bookkeeping software useful for capturing results of behavior and cognitive task analyses. Analogous to the systems engineering tools Doors, Core or Slate.	
TestLog	Demonstrated human aspects of product testing that need to be documented as part of test planning, overseen during test execution and documented as part of post-test analysis.	
DeSAT and SuperSAGAT	Situation awareness based cognitive engineering tool that generates validated requirements	Product quality was so poor that incorporating it in APSE was considered detrimental to project goals.
Model Center	Integration of independent analysis software	Used for uncompleted AOA exercise

DeSAT and SuperSAGAT are software aids that instantiate the situation awareness approach to cognitive engineering. The quality of the software's interface and functionality was poor and would not have shown cognitive engineering off to good advantage in the eyes of systems engineers. SA Technologies will shortly release version 2 of the software which is expected to be an improvement. The exercise was invaluable, though, because it spurred the interdisciplinary discussion of the differences between informing design and specifying design. The discussion led to a paper jointly authored with Dr. Robert Hoffman that was printed in the September/October, 2008 issue of *IEEE Intelligent Systems* (28).

The Model Center exercise was initiated in support of an Analysis of Alternatives (AOA). The design team was in the process of building models for inclusion in Model Center at the end of the contract performance period. As was stated earlier, we aggressively and ambitiously pushed for

a solution to the problem of embedding human considerations in the acquisition process. We knew that an actual AOA can take as many as 18 months for a large program. With only a few months remaining, undertaking even a simulated AOA was ambitious. The software was installed. Tutorials were completed. By executing the first seven steps of the AOA process, products were produced that show the promise of the approach taken to include human considerations.

For the AOA demonstration, a university intruder management was selected as the example system. We completed six steps of the Army's eight-step AOA process, see figure 18. We planned to analyze a low-capability and high-capability alternatives.

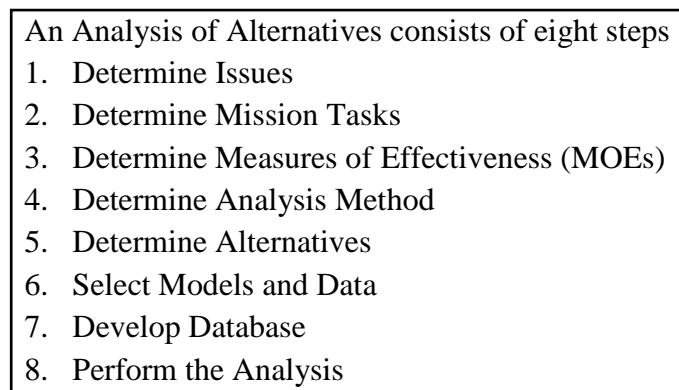


Figure 18: Eight-step AOA process

Cognitive engineers reviewed the AOA analysis methods and recommended that we incorporate the educational goals of the classroom building which had been previously excluded from the work. This was advisable because the study was treating the construction of a new university building as well as the intruder monitoring center. Steps one through four of the analysis of alternatives were repeated to capture pedagogical features of the chemistry labs.

The inclusion of human systems integration and cognitive design attributes illustrated how an analysis of alternatives could be approached and how precursor data must be prepared to enable successful execution. The analysis of a university intruder response system provided additional benefit from the work. We felt this study would be publishable on its own merits and explored publication avenues.

We conducted an investigation of the Brahms software. Brahms supports behavior task network modeling. It differentiates itself from products based on the Micro Saint simulation engine but being more agent-based which allows it to better capture the intent of the people being simulated. However, it has the same time-basis for assessment as do the Alion products, which does not help to capture the desired improvements in performance that the Air Force seeks from cognitive engineering application. Brahms, developed out of NASA Ames, is free for research and to the

government, but there is not a licensing approach for contractor use. This makes it difficult to recommend Brahms for professional use. The Brahms web site (29) describes a product to incorporate visualization functionality, but this is not part of the available release and must be explored further.

We explored Trident Systems Interchange SE with great interest. We felt that if we could Interchange SE as the backbone this would help to pave the way for a demonstration in the NAVSEA Navy Capability Development Process. While the Navy has not maintained use of the HCDE in the Navy Capability Development Process, it has retained Interchange SE. Interchange SE makes available a central data store with a common interface that allows multiple commercial and custom software tools to be seamlessly integrated. When we first explored incorporation of Interchange SE in the APSE presentation and discovered a single license cost \$72,000. This would have subsumed our entire software budget. We expressed this concern to Trident Systems.

Nearly a year later, we visited Trident Systems to discuss licensing and availability of Interchange SE. During our visit to Trident, we discovered that a new Interchange SE release was imminent. This release, version 3, will be free and downloadable. The Interchange SE marketing plan now focuses more on consulting, training and set-up services. Interchange SE 3.0 is not in a form which “an individual user could be turned loose to use it.” Since we did not have the budget to engage Trident, we opted instead to purchase Model Center by Phoenix Integration.

### **3.5. Market Development, Awareness and Education**

This project exhibited many attributes of the design of a socio-technical system. Embedding cognitive systems into systems engineering has both a technical side, i.e. the model process and toolset required by the SBIR topic, and a human side -- people’s awareness of the emerging discipline, their familiarity with the value it engenders, their prejudices about what belongs inside the envelop of a system under consideration, as examples. It was interesting to note people’s reluctance to treat both aspects of the socio-technical system as acquisition.

While the color-of-money considerations required that a product result from this effort, the product had no value to acquisition practitioners without an appreciation of cost and performance issues that could not be adequately treated if HSI and cognitive engineering were not included as an integral part of the acquisition process. If an a priori key performance parameter had been designated for this SBIR effort, it might have best been stated as the number of minds changed – the number of people persuaded of the value of human systems engineering -- during the period of performance. Of course, this is a difficult parameter to measure; the authors can offer no objective measure of success against this metric. In the following subsections, we describe the

efforts we made to increase the number of ticks on the positive side of the value balance. The right side of figure 8 shows the subsection titles.

Presentations in 2006, some predating conclusion of the phase II contract, what may be called “bandwagon” talks. People wanted to know about the work to introduce cognition into acquisition; our goal was to get them involved as insiders as the model process was being developed. It was better to have them contributing to our work as it evolved rather than criticizing the work after it was completed.

### **3.5.1. Meetings**

Since the July 2004 Air Force Scientific Advisory Board report, *Human Systems Integration in Air Force Weapon Systems Development and Acquisition* (30), individuals interested in acquisition, particularly those whose practices are related to HSI, have been heatedly discussing the means the process and means for inserting HSI into acquisition. Our team participated in formal and informal meetings in which solutions were debated. We argued that the human aspects were as important, if not more important, than any technical solutions put forward.

#### **3.5.1.1. Intelligent Enterprises Working Group**

In 2006, the author was asked to present to the INCOSE Intelligent Enterprises Working Group (IEWG). Tenets of IEWG are of interested to this work because they look at systems as aggregation of people using peripherals. This perspective is in keeping with the pre-industrial revolution model discussed early. It is also attractive because it establishes a continuum of sorts from systems that are only people to systems that are principally machines run by software. So the same acquisition process could, theoretically be applied to a special operations force as well as to an aircraft or naval vessel. The author reviewed the challenges of human centering to provide improved performance and cost, the technical challenge of being able to answer the mail that CHI Systems’ Dr. Wayne Zachary felt was of the greatest concern when speaking at the MIT Humans and Technology Symposium (31) which is described in more detail in section 3.5.2. The various initiatives to address the challenges both in the government and commercial sectors were describe, such as the Pew and Mavor (32) study for the National Resource Council which eventually turned out such a confusing report, and Microsoft’s hiring of anthropologists to inject the study of how people use tools into their product development process. The cultural change aspects of this project were described – inclusion of all acquisition stakeholders (a community solution), making the change mechanism available, attractive and relevant, and making changes understandable, transparent to people affected by them.

Concerns about the seven +/- 2 HSI domains was expressed even at this early stage. HSI is broken into nine domains – Manpower, Personnel, Training, Human Factors, Environment, Health, Safety, Survivability, Habitability. Some organizations do not include habitability. Others bundle occupational health with environment. These were arrived at because this is the

way in which armed service branches are organized. What about other human concerns which need to be considered? For example, social regard for design, are troops targeted more hostile when their humvee has a military design versus more of a civilian look? How does culture play into design? Why aren't physiological and medical considerations included? How should they be? The latter omission could turn out to be politically significant particularly for the Air Force HSI Office as the Human Effectiveness Directorate merges with the 311th Human Systems Wing to become the 711<sup>th</sup> Human Performance Wing.

Finally, the question of whether all aspects of the human mind were being considered was raised. It was pointed out that cognition is one of three aspects that affect performance. The other two are affect, or emotion, and the third is conation, which can be loosely equated with motivation or desire. Members of the IEWG resonated with this because these are important considerations if systems are regarded as collections of humans using tools. Indeed, military leaders recognize the importance of affect and conation, but these two aspects of the mind do not seem to be considered important in the design of military systems.

#### **3.5.1.2. HFES 2006**

Just as the prime contractor networked with fellow systems engineers, Klein Associates, the cognitive engineering subcontractor to this effort, performed similar awareness-raising at HFES. The networking was more one-on-one than the presentation made to the IEWG, but was similarly designed to familiarize colleagues with ongoing activities and issues.

#### **3.5.1.3. Klein Associates Brownbag Sessions**

Starting in March, 2007, systems engineers were invited to participate in lunch time discussions hosted by the cognitive systems engineering group of Klein Associates. Discussions were about improvement of cognitive [systems] engineering practice and how to increase the scope and scale of the practice by expanded contributions to acquisition. Topics included:

- APSE. A presentation was made and formative feedback was obtained.
- A cognitive engineering training seminar consisting of six half-day modules that could be selectively presented for a target audience. A version was developed and presented at the 2008 HFES Annual Meeting. Additional funding was sought in order to turn it into a regular event similar to the human factors training provided by University of Michigan.
- Certification of the cognitive engineering training seminar by INCOSE so it could be presented regularly to systems engineers.
- Certification of cognitive engineering practitioners. HFES past president Dr. Marv Dainoff was a member of the human factors *certification* board and was querying the group about skills and abilities that would be distinguishing.
- What would go on the short list of essential cognitive engineering references?

- Blogs and list serves as communication and education mechanisms.
- Establishment of a cognitive systems engineering speakers bureau.
- *The Cognitive Systems Engineering Landscape*. Four participants in the brownbag sessions, Dr. Cindy Dominguez, Dr. Gary Klein, Dr. Gavan Lintern, and Dr. Laura Militello have been working for several years on an overview paper of cognitive systems engineering. They were encouraged to complete it for a special issue of Cognitive Engineering and Decision Making being edited by Dr. Richard Pew and Dr. Emily Roth. The deadline passed before edits were completed. Dr. Militello was offered payment under this contract if that would help to complete the article.

The paper was conceived to be a general explanation of cognitive systems engineering for lay people. In the past, fine points included about a particular school or philosophy of cognitive engineering rendered the article and articles like it opaque to systems engineers and project managers. At HSIWG gatherings, systems engineers still didn't know what cognitive engineering was; they were not prepared for a discussion of its finer points.

In December 2008, after some encouragement including the offer of payment, the edits had been made and the article was being finalized by its authors. A slimmed down version has been solicited for the upcoming INCOSE *Insight* publication on cognition.

The participation of the systems engineers present, this report's author and Mr. Michael Mueller of the Air Force Center for Systems Engineering, helped to turn this group into one that was more outward facing. Outward facing means the group is addressing its customers as opposed to people who practice within the same specialty. We captured and distributed minutes, helped to shape seminar content, and encouraged the completion of important publications.

#### **3.5.1.4. HSIS 2007**

In March 2007, the American Society of Naval Engineers hosted HSIS, HSI Symposium. HSIS "provide[s] a forum for HSI experts from military, industry, and academia to exchange information on emerging military systems, promising research, and the benefits of effective HSI implementation. This conference seeks to share lessons learned from military, industry, and academia to support future improvements in design processes and systems." (33)

This was primarily an intake session. We engaged display vendors to understand their practice and their offerings to try to understand how they contributed to the developing model process and how APSE fit into the mix of products and services. The two most important insights were the following: 1) the importance of the lexical challenges of cross-disciplinary practice and 2) the inward looking posture of the HSI community. Just as with the brownbag sessions and INCOSE, practitioners find more comfort in talking with their peers than with people who can

receive value from their products and services. The latter insight strongly influenced our subsequent efforts.

### 3.5.1.5. Beyond Phase II Conference

In August, 2007 the National Defense Industry Association sponsored *Beyond SBIR Phase II Conference & Exhibition 2007: Bringing Technological Edge to the Warfighter*. The conference allowed SBIR participants to arrange 15-minute sessions with prime contractors, government acquisition managers, the investment community, and manufacturing. Ten appoints were set up. Table 7 lists them.

Table 7: Beyond phase II conference meeting summaries

Contact	Outcome
Mr. Martin E. Trujillo Liason to SPAWAR PMW-180 PEO C4I & I/O	Sent him APSE flyer. Trujillo said he would send email around his organization. "Can only lead a horse to water..."
Mr. Jack Griffin NAVSEA SBIR Program Coordinator Undersea Warfare Center Division	Interested in setting up a CRADA to have NAVSEA systems engineers test use of APSE. Main purpose for us was to obtain a testimonial about the product for marketing use. CRADA abandoned on Navy side.
Andre Valente, PhD Chief Operating Officer Tactical Language and Culture	Dr. Valente was interested in exploring cross-cultural training product in context of HSI. Explained contract and introduced him to HSIWG. No follow-up.
Raj K. Aggarwal, PhD Vice President Global Technology Engineering and Technology Rockwell Collins	He didn't really see how it fit in with what they did. Asked if we'd met with systems engineers and cognitive engineers to determine if these were the right questions we need to be answering. Mentioned the phase I Glen Helen meeting. Suggested working with their organizations Linda Simmons.
William A. (Bill) Freiberg Capture Manager Advanced Combat Aircraft Systems Phantom Works The Boeing Company	Said this was fascinating stuff.  At first he said they don't use systems engineers, but then he said that as part of the capability definition and design they do Design of Experiments which are supported by systems engineers.  Thought APSE fit into the "Lean" buzzword. He triggered off the high value activities to make the connection between lean.  He saw how this could support them in what they did.  Said someone would follow up with me, perhaps Steve D'Urso (UIUC alumni president). No follow up took place.



Table 7: Beyond phase II conference meeting summaries (cont'd)

Contact	Outcome
<p>Stanley U. Levy</p> <p>and</p> <p>Larry Butler HMS/Maintainability/Testability Product Integrity Engineer Space and Airborne Systems Engineering Raytheon</p>	<p>Larry is a systems engineer. Couldn't understand where the requirements came for the kind of things APSE was talking about. He said they got MIL STD 1472, Human Factors, which he said he could quote. With the IPT structure chart, he got the connection to MANPRINT.</p> <p>I told him about NAVPRINT, AIRPRINT and JOINTPRINT. He said they didn't do this very well. They have a guy, Bob Schwam who is a human factors guy. He thought Bob would be willing to review this as part of an internal study. Need to better understand the _PRINTS if these requirements are coming down the pike. I showed them Dennis Folds' charts and they were interested.</p> <p>Sent one-page APSE flyer to Larry and Stan along with Dennis' charts on HSI and the link to our HSI web page.</p>
<p>Andrew Bodkin Principal Bodkin Design &amp; Engineering</p>	<p>No use for APSE.</p>
<p>Ron Szymanski US Army CERDEC</p>	<p>Suggested we contact DAU and show off APSE perhaps as a complement to the courses they're providing. (Note: Jack Griffin made the same suggestion.) I showed him Dennis Folds' charts from the HSI seminar. Sent him a copy of them.</p>
<p>Daniel (Dan'l) S. Thomas Program Manager Detection Systems General Dynamics</p>	<p>No use for APSE.</p>
<p>Michael Zammit Missile Defense Agency SBIR/STTR Program Manager</p>	<p>Mike asked me to check the MDA 6.3 SBIR announcement for Human Effectiveness topics. He thought sure there were some. He suggested that I get the contact names from those offerings, send them to him with the one page flyer about APSE and he would get it into those people's hands. Mike sent me references, but no contact names were listed.</p>

Each of the interviews raised the awareness of the HSI and cognitive engineering in the minds of the contact individuals. They were a representation of the audience that must be reached. Some people heard about HSI for the first time. Others saw no relevance. Some, like Raytheon's Larry Butler, were aware of human factors requirements, but were unfamiliar with the broader practice of HSI and had not been introduced to cognitive engineering at all.

A panel made up of the SBIR leaders from the Air Force, Army and Navy opened the conference sessions. At the conclusion, they took questions. This report's author asked the first question which was, "What if the solution to a capability need stated in a SBIR is not technical, but, instead, is related to changes in human performance much in the manner that a DOTMLPF solution could be an alternative to a materiel acquisition?" Each responder was able to describe the importance of humans and HSI in their organization, but did not directly relate the importance to manifestations in the SBIR program. Two more of the remaining five questions taken by the panel related to the incorporation of humans in capability solutions. This created a buzz among conference attendees. HSI and cognitive engineering became topics of break and lunchtime discussions for the following two days. Unfortunately, the exhibiting vendors and people like those listed in table 7 were unaware of this because they were not able to attend presentation sessions and took their breaks and lunches away from the other attendees. This is why the face-to-face interviews were important educational opportunities from the perspective of SBIR AF05-071.

As stated above, the social engineering of the cultural change required for a solution to the problem posed by this topic was primarily accomplished by changing one mind at a time. The question to the panel and the interviews were opportunities that were sought or created as part of our approach.

#### **3.5.1.6. CHI/IHMC**

October 2007, CHI Systems and the Institute for Human Machine Cognition (IHMC) hosted a two-day workshop titled *Merging Cognitive Systems Engineering into Systems Engineering: Implications for Large-Scale Information Systems Procurement* (34). "The Workshop will promote discussions that consider real world constraints and challenges in the procurement and design of human centered technologies. Participants will discuss lessons learned and their best ideas about how to fix "the system." The Workshop will take steps toward creating a roadmap for human-centered procurement that goes significantly beyond current guidance (e.g., DoD Instruction 5000.2R)." (34)

Workshop participants appeared to align themselves into researchers and people with experience in product development. Researchers spoke eloquently about theories of complexity and resilience and affordances. These words confused the development community who didn't understand how what the researchers were propounding fit within the world of development. When the simple definition of HSI (see below) was challenged by researchers, the author pointed out that "No one outside this room cared at all about the theories which were being put forward by researchers." The development people affirmed this statement. While project managers and the engineering community see no value or have no appreciation of human integration, the theories had no place to in practice. It became apparent that research community representatives were advocating the need for more research dollars in order to "fix the system."

The PowerPoint (figure 30, Appendix C) paper prototype of APSE was presented to the group. There was not universal enthusiasm, but several people wanted the product immediately and were even interested in acquiring access to the early Backpack prototype. Some of the requestors appreciated the content. Others embraced it as a planning tool.

### **3.5.2. Papers and Presentations**

#### **3.5.2.1. MIT Humans & Technology Symposium**

In January, 2006, MIT's Humans and Automation Laboratory sponsored the Humans & Technology Symposium. Human factors, cognitive engineering practitioners and students participated in this three-day study that took place between the phase I and phase II activities of the SBIR topic. The presentation reviewed the operational challenges, recent history of integrated, concurrent software environments and spoke about the integration of disciplines.

#### **3.5.2.2. The Ninth World Conference on Integrated Design and Process Technology**

At the invitation of Jack Ring, a paper was prepared and presentation was made at the IPDT Conference. The paper's abstract is below.

“Military and commercial entities throughout the world are recognizing that systems which take advantage of, and do not impede, human cognitive capabilities deliver improved performance. The United States Air Force, Army and Navy have funded studies to investigate and develop integrated, human-centered design support methodologies and tool sets. This presentation provides an overview of those efforts and speaks specifically to work funded by Air Force Research Laboratory's SBIR program. Designing systems that include human participants within the system boundary is not a new topic; it has been under study by those interested in systems' realization for over three decades. However, customary practice defines humans' capabilities and concerns, their development, and their rotation/promotion cycles to be outside the boundary. This hinders the holistic consideration of the continuum from wholly materiel systems to systems comprised entirely of human components. Procedural and cultural barriers to a cost-effective, implementable process have been identified and will be described. Criteria for developing a tool set to support a process that meets institutional needs without constraining competition will be outlined. A transition scenario for satisfying the DoD's near term vision of practice will be elucidated. Finally, the need for a long-term evolutionary process vision will be discussed.” (36)

The presentation was a more elaborate version of the informal briefing that was given to IEWG. Air Force, Army and Navy HSI efforts were described. This SBIR effort and participating companies were introduced. The Pew and Mavor NRC study was shown. Web sites with reference materials for interested individuals were shared. The two thrusts of the activity,

technology for “answering the mail” and cultural change for creating value, were highlighted. Barriers to success and paths to resolution were described. Principal among these paths was an early description of APSE. This was to make people aware that the product was coming. The HSIWG was also introduced along with contact information for people who wanted to participate in the group.

#### **3.5.2.3. IEEE Computer**

Discussions at the Klein Associates brownbag sessions modified the perspectives of cognitive engineering pioneer Dr. Gary Klein. The thesis or the article was “Cognitive systems engineering is a value-added technology offering many benefits that outweigh its costs.” (35). The paper was a breakthrough in the sense that it was reaching beyond the cognitive engineering community into arenas where that value could be realized by customers. Cognitive systems engineering was defined as “the effort to support the cognitive requirements of work.” This definition was first crafted, to our knowledge by the paper’s co-author and participant in this effort, Sterling Wiggins. It is the simplest and most easily comprehended of all those that were uncovered during this study.

Another idea that came out of the brownbag discussions was the value cognitive engineering could bring to project management. Cognitive engineers have expertise in team design and decision making that could help managers to tailor program structures. Additionally, their knowledge elicitation skills demonstrably helped to improve the efficiency of meetings on the programs like DDX.

#### **3.5.2.4. IEEE Intelligent Systems**

Discussions about the influential differences between “informing” design, the approach taken by cognitive engineering and “specifying design” that arose from our exercise of Goal Directed Task Analysis resulted in the publication of a paper jointly authored with Dr. Robert Hoffman (28). The importance of replicas or “shall statements” for directing software development was emphasized. Dr. Hoffman described how this can be achieved as part of cognitive task analysis.

#### **3.5.2.5. 2nd International Conference on Applied Human Factors and Ergonomics**

At Dr. Marv Dainhoff’s invitation, a paper was prepared and presentation was given for AHFEI. The session theme was HSI. The focus of the paper was on the HSIWG and the progress it had made. The abstract follows.

“Since February, 2006, the author has served as co-leader of the International Council on Systems Engineering’s Human Systems Integration Working Group (INCOSE’s HSIWG). The HSIWG’s purposes are to facilitate embedding human systems integration within systems engineering and to promote the benefit of placing the proper focus on the role of

people in the development and operation of systems. This paper explains that purpose, describes the group's progress and accomplishments, examines the barriers to success, and explores future opportunities for the working group, for societies of professionals and for individual practitioners.” (36)

The briefing focused on the need to look outward, to connect with customers up the demand chain and be aware of what was being provided through the supply chain. The need for all stakeholders in the APSE chain (from program managers to cognitive engineers) to illustrate the value of the services they provide was emphasized. Fifty copies of INCOSE *Insight* special HSI edition (5) were distributed to session and conference attendees. A list of the APSE deliverables was also provided as a handout.

### 3.5.3. HSIWG

This project's topic statement implies that systems engineering is the accepted state into which cognitive engineering is to be inducted. In order to achieve the desired penetration into systems engineering process, a working group was initiated within the technical structure of the INCOSE. The group was chartered under a systems engineering enabler function which employs a very narrow definition of specialty engineering to include manufacturability, cost, reliability, serviceability – all the 'ilities. Starting from two members in January 2006, the group has grown to over 150 participants. It meets twice a year at the International Workshops in January for four days and at the INCOSE International Symposium in June or July for a half day session.

The first task of the group was to establish purpose and vision statements. The author moderated a gathering of nineteen people who crafted the following statements.

**PURPOSE:** The INCOSE Human Systems Integration Working Group will facilitate embedding HSI within Systems Engineering, promoting the benefit of placing the proper focus on the role of people in the development and operation of systems.

**VISION:** HSI is embedded in SE practices, leading to the efficient delivery of effective systems.

The following year, a succinct definition of HSI was crafted. The author put together a white paper that captured 49 known definitions of HSI. At the workshop sessions, a group of 35 whittled the definition down to 21 words. From January through April, listserve discussions were conducted to refine and gain acceptance for a definition. The resulting 26-word definition is below.

*HSI is the interdisciplinary technical and management processes for integrating human considerations within and across all system elements; an essential enabler to systems engineering practice.*

This is the definition that was seen as too simplistic by researchers at the CHI/IHMC gathering in October, 2007. What they did not appreciate was systems engineers did not universally agree

that human considerations belonged inside the system design envelope. The INCOSE definition eliminated, while not having the ability to change people's minds, became an official statement that essentially said, 'Humans are a part of the system.'

Another important aspect of the definition was that it did not state that systems engineers were going to execute human systems integration tasks or become the experts. This was an important consideration because the group did not want to alienate those who had the skills required to perform the work.

The question must be asked, if the SBIR topic required researchers to address cognition, why the emphasis on HSI in the systems engineering community? As commonly proscribed, HSI includes the domains shown in figure 19. Cognitive engineering is a subset of human factors engineering. In practice, cognitive engineering impacts, manpower, personnel, survivability, habitability, team dynamics, and the sensory aspects of human factors. Cognitive engineering is also instrument in development training requirements. So its influence permeates HSI practice but is not identical to it. Equating HSI with cognitive systems engineering was the mistake made in the Pew and Mavor NRC report (32). The convolving of the two terms has resulted in confusion and an unfortunate backwash against cognitive engineering.

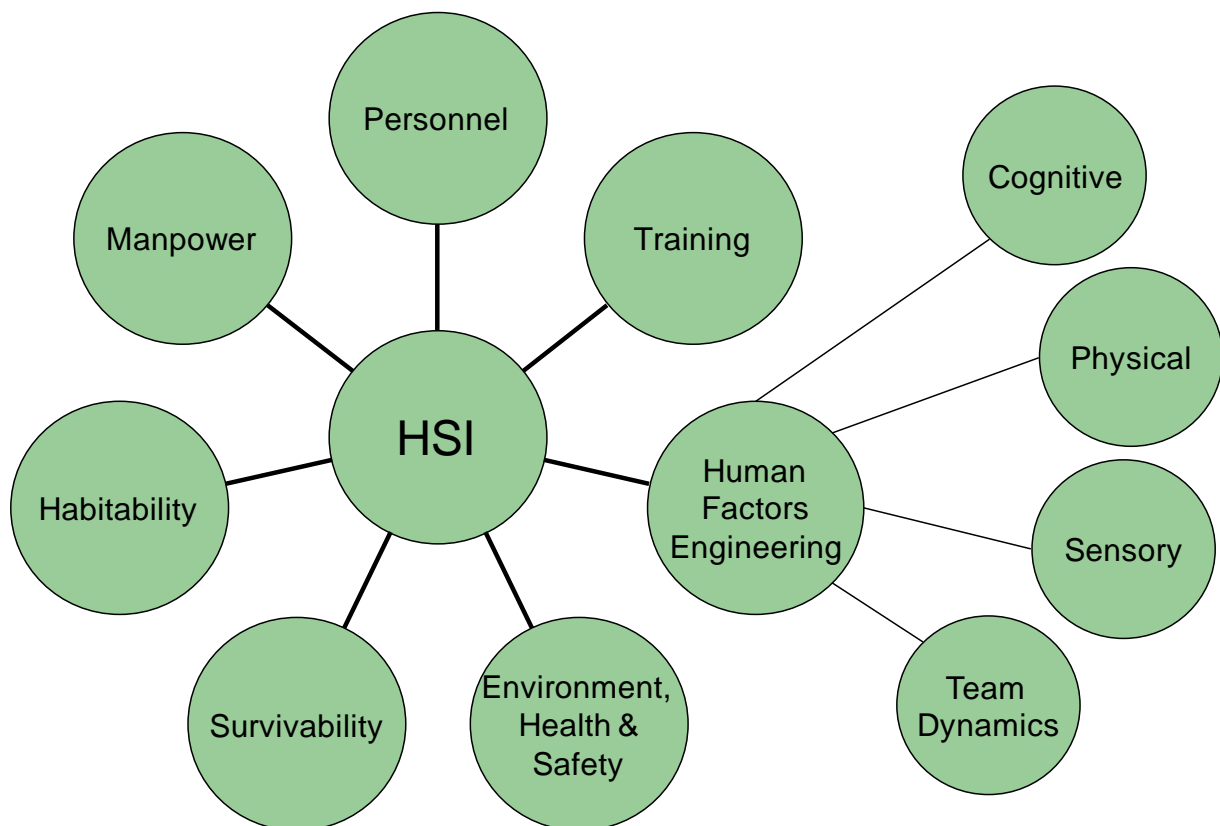


Figure 19: HSI domains and the relationship of cognitive engineering

### **3.5.3.1. Education**

#### **3.5.3.1.1. Dr. Dennis Folds, Georgia Tech Research Institute**

At the suggestion of then director of the Air Force HSI Office, Dr. Richard Drawbaugh, Dr. Folds was invited to present a seminar on HSI practice at INCOSE's 2007 International Symposium. INCOSE leadership paid Dr. Folds' speaking fee on this first occasion. At that time, HSI participants were advancing their own theories and opinions about HSI practice. We wanted to hear from an actual HSI practitioner to understand how it worked. Dr. Folds has experience in all the figure 19 domains save Habitability. He spoke for a full day and after made his presentation charts available for posting to the web. They are available from <http://www.incose.org/practice/techactivities/wg/hsi/> and provided source material for much of the HSI APSE content.

The following January, Dr. Folds spoke for a half-day at the 2008 International Workshops. This time, his topic focused on HSI Analysis. Dr. Folds' speakers fee was funded by this contract effort as INCOSE declined to pick up his fee. As with the 2007 seminar, Dr. Folds provided his slides for posting, but we were unsuccessful in getting INCOSE volunteers to post the charts on the open HSIWG web site. They were made available to INCOSE members through the working group's SharePoint web site and can be accessed via APSE. This presentation also provided source material for the HSI APSE content.

#### **3.5.3.1.2. Dennis Carlson, Pit Stop Engineering**

Dr. Mary L. Lozano, Ph.D, an anthropologist working for Northrop Grumman Electronic Systems, recommended Mr. Carlson as speaker for HSI. She touted his unique, philosophy of design which places "humans first, machine second" as the best way to achieve mission performance goals. Mr. Carlson, an award-winning designer, takes an approach that differs from all others that were encountered during this effort. Motivated by his experience in NASCAR design, he wraps systems around the people who use them. Mr. Carlson provided a half-day seminar to the HSIWG.

A primary feature of his presentation was his inclusion of testimonials which subjectively documented people's satisfaction with his work, but also supplied numbers regarding the operations costs saved. We were advised by marketers we consulted that testimonials were essential for advertising the value of APSE for our target audiences. Mr. Carlson's presentation dramatically illustrated their power and influence.

### **3.5.3.2. Alliances**

#### **3.5.3.2.1. HFES-INCOSE Memorandum of Understanding**

A memorandum of understanding (MOU) was drafted in the fall of 2007. It was submitted to the HFES executive director in October of that year. Shortly after the submission, the HFES System Development Technical Group (SDTG) made modifications to its charter which positioned it as the leader HSI technical group within HFES. The charter revision provided an immediate point of intersection between the two groups and cross-over discussions were initiated at the 2007

HFES annual meeting. This arrangement created a bridge between HSI and cognitive engineering practitioners and systems engineers which will help members of this practitioner sets to understand what processes, methods and tools are needed to have to make an effective impact on mission performance and ownership costs.

The MOU went through a review process and revision. The revised version was submitted to INCOSE leadership one year later. The MOU is intended to establish a relationship between the leadership of the two organizations so joint strategies can be undertaken.

#### **3.5.3.2.2. IEEE Systems, Man, and Cybernetics Society**

IEEE SMC vice president Dr. Ellen J. Bass was invited to present to the HSIWG at the 2008 international workshops. The goals of SMC are similar to those of INCOSE, though, like HFES, the emphasis is more on how to practice and how to improve practice than in extending the practices of SMC members. Dr. Bass was open to joint activities. HSIWG leadership transition slowed the process. Dr. Bass attended the 2008 AHEI meetings in July at which a student of hers presented. Informal discussions of linked activities were continued after the session.

#### **3.5.3.3. Publications**

##### **3.5.3.3.1. Appendix to Systems Engineering Handbook**

Members of HSIWG contributed to an HSI appendix to the INCOSE Systems Engineering Handbook version 3.1 (2). Not only does this have value for the influence it has over acquisition policy, it also brings the handbook into line with the content of IEEE 1220 which is laced with references to human systems engineering practice.

##### **3.5.3.3.2. Integrating the Human in Every System**

In April 2008, HSIWG sponsored a special edition of INCOSE Insight magazine (5). The magazine is distributed to the more than 5,000 INCOSE members. Fifty copies were also distributed at AHEI and 100 were provided to individuals at the Air Force Center for Systems Engineering by request. Four hundred copies were provided to the vendors at I/ITSEC 2008. Table 8 lists the contents, authors and topics contained in the issue.



Table 8: Contents of the *Insight* special edition on HSI

Section/Article	Author(s)	Emphasis
“The Pervasive, Indispensable Human ”	Michael Mueller	Issue Overview Humans impact all systems
Extension of Specific HCI Methods and Tools for Higher-Level HSI Application	Major Nick Hardman Lt Col John Colombi	HSI Methods & Tools HSI Technology
Building to the HSI Demonstration	Dennis Folds	HSI methodology and tools HSI analyses HSI-systems engineering synergies
Talking the Talk – Cross-Discipline Terminology Challenges	Jennifer Narkevicius John Winters	Impacts of education and training segregation on language and practice Methods for successfully bridging the multiple disciplines (domains, systems engineering, HSI, PM, funding)
JPRINT Overview	Jen Narkevicius, John Lockett, and Gretchen Lizza	HSI Policy – evolution and needs HSI organization HSI technology forecasting and prioritization HSI training and education
HSI is not just for Department of Defense – Contrasting HSI Practice in Military and Commercial Sectors	John Winters et al	HSI methodology and tools HSI in organization HSI Policy HSI economics Training and education
HSI in Commercial Ship Design	Alexander C. Landsburg	HSI in lifecycle Economics of HSI HSI Tools and methodology HSI in organizational structures
10 Best Practices of HSI	Editors	Summary pulled from the other articles and author recommendations
Sidebar of HSI Resources	Editors	

### 3.5.3.3.3. Cognition: Pursuing the Next Level in System Performance

A second special edition of *Insight* magazine is in preparation. This issue’s theme is cognition. It will go to press in April, 2009. Authors have been approached and, with some exceptions, have been confirmed. As can be seen from the planned contents given in table 9, the emphasis

of the issue is on successes – what has worked in practice. The issue is intended to show examples of how systems and cognitive engineers have worked together successfully in the past and provide tips on how it should be done.

Table 9: Contents of the *Insight* special edition on cognition

Section/Article	Author(s)	Emphasis
Editor's intro -- Deal	Deal	Overview of issue
Why Cognitive Engineering is Important?	TBD	Customer demand focus
The Cognitive Systems Engineering Landscape	Laura Militello	Definition of domain
Situation Awareness	Laura Strater	Success in applying situation awareness methodologies
Modeling User	Clyde Wetteland	Overview of Alion successes in behavior and cognitive modeling
TBD	Paul Picciano	Successful use of Aptima tools
Submarine Design	Sterling Wiggins	Successes in team design of submarine control rooms
Pistop Engineering	Dennis Carlson	Successes in human first, machine second
Architectures and Cognition --	Chris Hale Vince Schmidt	
Job Aids Design and Effectiveness	Matt Waters	Overview of DLA/DAPS approach to job aid design, its successes and how it is funded
Sidebar A – Top Ten List	Editor	Summary pulled from the other articles and author recommendations
Sidebar B -- Cognitive Engineering Resources	Editor	

The greatest concern for the issue is the difficult experienced with getting an authoritative government representative to write the demand side article to start off the issue. Many of the people who championed this work have retired or moved on to new positions. There are HSI advocates, but it is difficult to find someone who is able to influence procurements who will champion the cause of cognition.

#### 3.5.4. Connector

By working to form collaborative alliances with competitors who were cognitive engineering specialists on the phase I effort and across awardees on the phase II effort, and because our skills sets were not competitive with theirs, we became viewed as a trusted entity. In addition, being a

founder and co-leader of the HSIWG put us in connection with people from the directors of the service HSI offices through experts in HSI, cognitive engineering and systems engineering practice.

We purposefully reached out into the project management community. We joined PMI and attended local chapter meetings, and read project management publications in order to understand their concerns and needs.

This position became an asset to all the communities touched by APSE. Here are just a few examples. When Richard Pew and Emily Roth sought systems engineers to review the special issue of CEDM magazine on embedding cognitive engineering into systems engineering, we were able to put them in touch with systems engineers who were HSIWG members. When Drs. Vince Schmidt and Chris Hale were working on human views to insert into DoD enterprise architectures (DODAF), we put them in touch with NATO representatives who were defining similar views for the United Kingdom's MODAF and with the AF HSI representatives who were attending the joint meetings of the two architecture groups. When Trident Systems was looking for a cognitive engineering house to collaborate on a reconfigurable user interface, we put them in touch with Klein Associates.

Our role as connector enhanced research, improved process and extended practice.

### **3.5.5. I/ITSEC Booth**

The I/ITSEC was selected as a challenge event for the project. I/ITSEC is a training, education and simulation event. Training is a component of HSI. Simulation is associated with the engineering world. From past experiences at the conference, we had developed the opinion that the I/ITSEC exposition floor was a collection of technologies in search of users.

We purchased booth space, designed and assembled a low-cost space and set up APSE for demonstration and trial. The floor was divided into sectors and personnel were sent out to assess whether vendors were aware of the relationship of their work to HSI and how cognition was incorporated in their development efforts.

As part of our outreach efforts, copies of the *Insight* HSI issue (5) were distributed to the vendor booths.

### **3.6. Phase III Marketing**

Our concern was that we could develop a marvelous tool that was never exploited. This had been the experience of other sites, such as HSIAC. At I/ITSEC, we heard that SE Trace, another tool developed for SBIR topic AF05-071, was similarly languishing.

We wanted to find a way to drive users to the APSE web site. We conceived to target market major Air Force acquisition program offices and their supporting contractors to make them aware of the existence and value – time/cost saving and improved systems – of APSE.

Three Dayton-area marketing agencies were approached and asked to provide estimates for developing marketing campaigns. One firm did not bid. A second wanted to develop a web site for us – we were not able to communicate to them that a web site was what we were marketing. A third marketer, one who specializes in guerilla marketing, advised us to find at least one user who would employ APSE and provide testimonials supporting the value propositions.

Project manager Carl Pritchard presented “The End of Project Management as We Know It” to the Dayton PMI chapter in August of 2007. He was contacted to obtain his inputs on our project goals. After a few minutes, he stopped the conversation. He said he was not interested in anything he had been told about the project. He advised we needed to develop a two-minute video that explained the problem and our solution in layman’s terms. We set out to develop an introductory video for APSE.

Throughout the period of performance, we took advantage of opportunities to demonstrate APSE in its early Backpack prototype, CMap and PowerPoint prototype versions. These helped us to sculpt the content of the product to user needs. They were also part of our marketing strategy. We used those ‘tastes of APSE’ as teasers to interest the community in what was to come.

### **3.6.1. Testimonials**

Dennis Carlson demonstrated the impact of testimonials. He videotaped the results of his work, applied for awards, and used prime contract project managers as spokespeople for the value of his work. We wanted to emulate his results.

Our contacts with Jack Griffin, NAVSEA’s SBIR manager, opened up an avenue to test with the systems engineering staff that support undersea warfare. The statement of work for a CRADA was developed. It included providing publishable feedback. The Navy deleted this task from the statement of work because it was against policy to provide such testimonials. The CRADA was subsequently abandoned.

### **3.6.2. Video**

In response to project manager Carl Pritchard’s challenge, a script was drafted by the design team. Award winning videographer Joanne Caputo was engaged to film the video. She reviewed the script and determined it to be a 20-30 minute video that would be expensive to produce. Ms. Caputo rewrote the script. It was bound at the beginning by a silent segment in which actors mimed the problem APSE was designed to solve and at the end by a second silent segment that demonstrated the positive results of APSE use. In between two spokespeople, one representing a cognitive engineering, one representing a human systems engineer, described product attributes, value and uses. The final product was approximately four minutes in length in comparison to Mr. Pritchard’s challenge of a two-minute piece.

The movie was previewed at AHFE 2007 for the audience including HSI session moderator Dr. Marv Dainhoff, past president of Human Factors and Ergonomics Society. His response, “Can I get a copy?”

### **3.6.3. Demonstrations**

Demonstrations were used to validate APSE product requirements. APSE was demonstrated in its various forms in the following venues.

- APSE CMap version reviewed by Klein Associates cognitive engineers mid-2007.
- A post-CMap prototype was reviewed informally at INCOSE International Symposium 2007 by Air Force HSI office representative Fran Greene and Booz Allen Hamilton’s Barbara Palmer.
- Paper versions were presented to interviewers at Beyond Phase II conference in fall 2007.
- The PowerPoint prototype was demonstrated at CHI/IHMC workshop in October 2007.
- Pages from the DotNetNuke version were presented at HSI Working Group at 2008 INCOSE International Workshops in Albuquerque.
- APSE was demonstrated to Klein Associates brownbag group in the summer of 2008.
- Review of APSE pages with cognitive engineers Gary Klein and Robert Hoffman in mid 2008.
- Pages from the DotNetNuke version were presented to CHI Systems’ Jennifer Fowlkes at AHFE International in July 2008. Showed Dr. Fowlkes the video and described our AoA activity.
- APSE was demonstrated and made available for test at our I/ITSEC 2008 booth.
- APSE was demonstrated to Booz Allen Hamilton, Air Force HSI Office (HSIO) contractor. Ms. Margaret Sampson of Booz Allen Hamilton was shown rough-cut of APSE film, introduced to deliverables-based approach and software exercises including AoA.

Each of these interactions either affirmed the direction that was taken with APSE or resulted in modifications or redesign.

## 4. Results and Discussion

### 4.1. APSE

#### 4.1.1. Deliverables

We proposed to build an open-source, web-enabled software application that instantiated a model process that embedded cognitive systems into systems engineering practice. That product, APSE, is built on the DotNetNuke framework (39). DotNetNuke is an open source web application framework ideal for creating, deploying and managing interactive web, intranet, and extranet sites securely. APSE fields are created in an interface shell. Content is held in an SQL database, another open source application. Database content populates the interface fields when a deliverable is selected. Manhour graphs are created in real time by Silverlight 2.0, a free downloadable tool provided by Microsoft that pulls numbers from the SQL database.

APSE is free to all registered users. There is no fee for registration. Registration merely helps us to track who is using the site and serves as a security check against hackers.

APSE serves five target audiences. After login, the main window comes up displaying a legend (figure 20) which defines the acronyms used for each of the audiences, stakeholders or users. Government program managers represent system owners. Contract project managers represent the contracting enterprise's management team, systems engineers, human systems integrators (referred to as human systems engineers in IEEE 1220 (3)) and cognitive systems engineers may

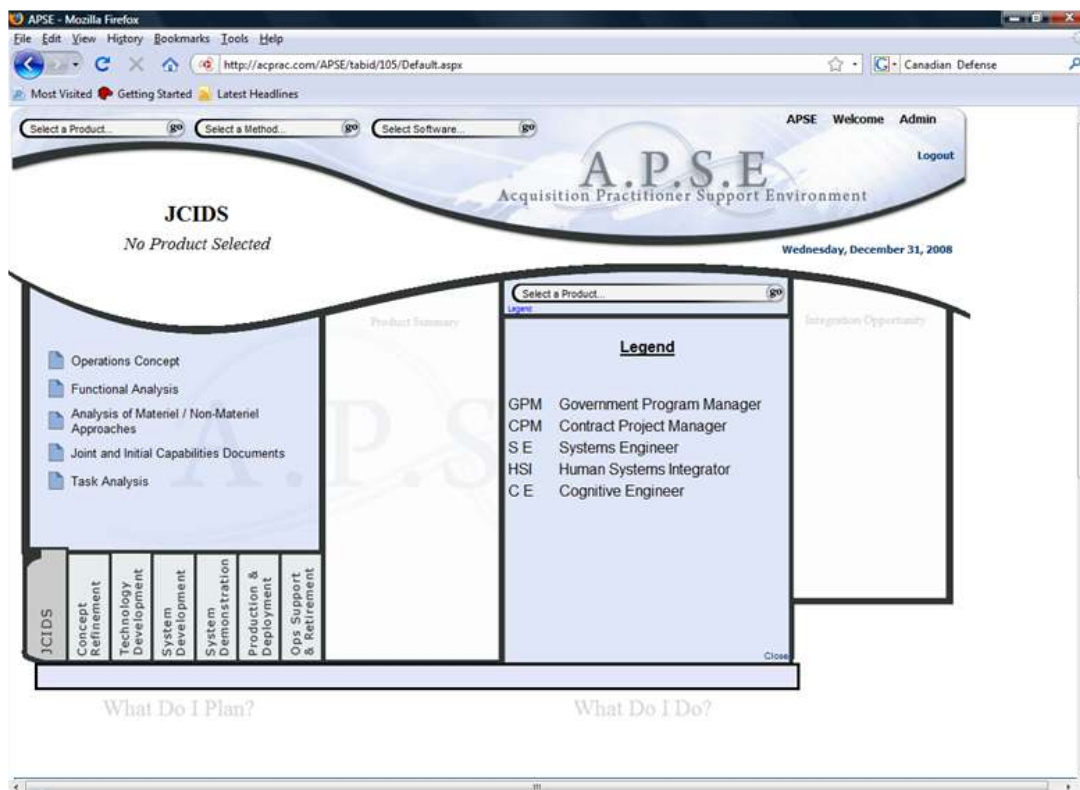


Figure 20: Target audience legend

represent either the owner or the contractor depending on the deliverable and context of the activity.

The APSE main page is shown in figure 21. The spacious, streamlined interface design has been termed “slick” in informal reviews and said to look like a *Star Trek*™ control panel. Fields dynamically resize when user click on them. This is helpful for those with vision degradation and for occasions when the APSE is briefed before an audience.

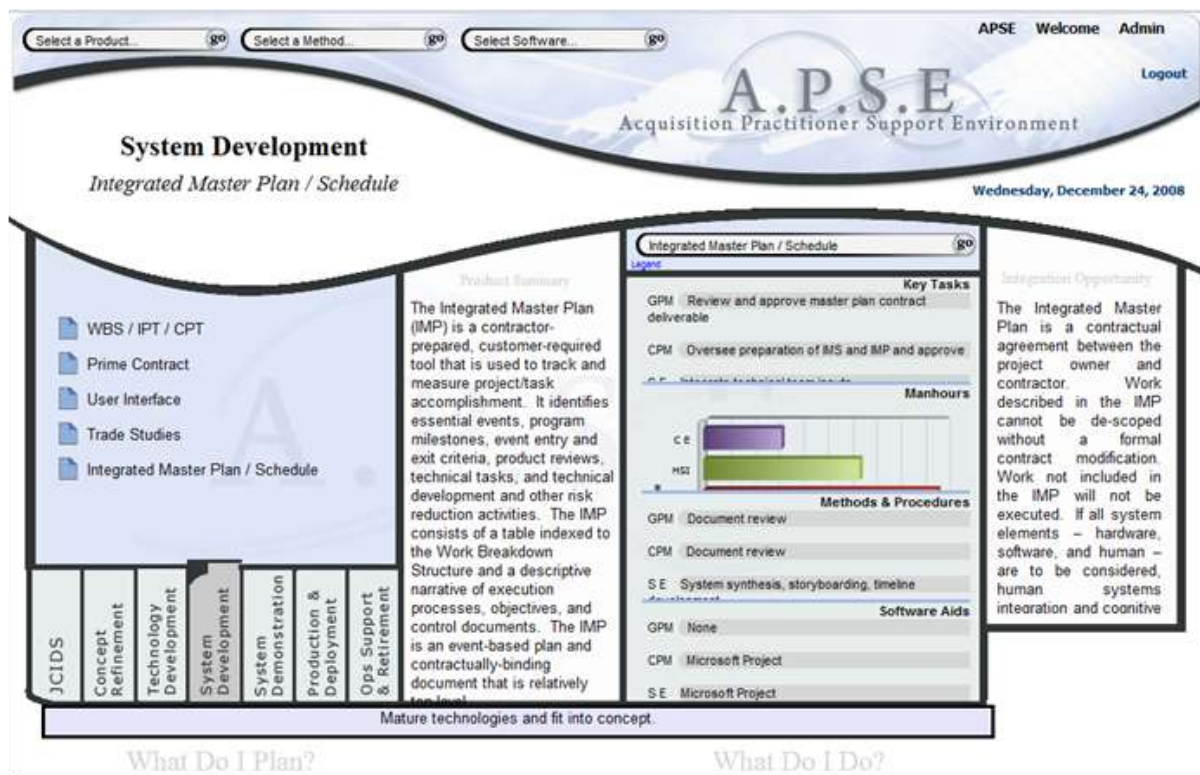


Figure 21: Sample APSE main page

Drop down menus at the top allow users to select from lists of deliverables (products), methods and software. Method descriptions are not yet complete. Software demonstrations still need to be linked to the drop down menu; they are currently stand-alone web pages.

The main page is divided horizontally into two fields. On the left the interface queries “What Do I Plan?” This is a message to users that the items on the left hand are those that need to be included in a project plan if cognitive engineering is to be successfully embedded. On the right the interface asks, “What Do I Do?” This tells users that guides to completing the deliverable are shown in the fields above.

Tabs on the lower left represent the seven phases of the model process APSE instantiates. JCIDS has been added as a precursor phase. Operations and Support and Retirement, separate phases in the DAS, have been combined. When a phase is selected, a brief description of the phase’s purpose appears in the message bar at the bottom. Selecting a phase reveals five deliverables associated with that phase. Deliverables may be updated or repeated in more than

one phase; they are introduced by APSE at the earliest point in which they are required in the life cycle.

When a deliverable is selected, the remaining main page fields are populated. In the center is the Product Summary which provides an abbreviated description of the deliverable and its purpose. On the far right, Integration Opportunity describes how this deliverable promotes collaboration and communication among representatives of the target audiences.

The third column provides a summary of the tasks, manhours, methods and procedures and software aids executed, expended or used by each of the stakeholder groups in the course of completing the deliverable. The accordions windows expand when selected by an APSE user to reveal all the content for a selected field (e.g., Key Tasks) for each of the five stakeholder groups.

The APSE deliverables page is represented in figure 22. A deliverables page provides more information about the product of interest.

Manpower numbers are shown by default when a deliverables page loads. This is because the greatest burden to incorporation of cognitive engineering in acquisition is the concern that it will overload a project manager's budget. Relative manhour estimates were created based on the author's experience in project estimation. Cognitive engineering and HSI manhours were provided or reviewed by cognitive engineering practitioners. Manhour estimates are labeled as To Be Reviewed (TBR) as the numbers must be tailored to the project at hand.

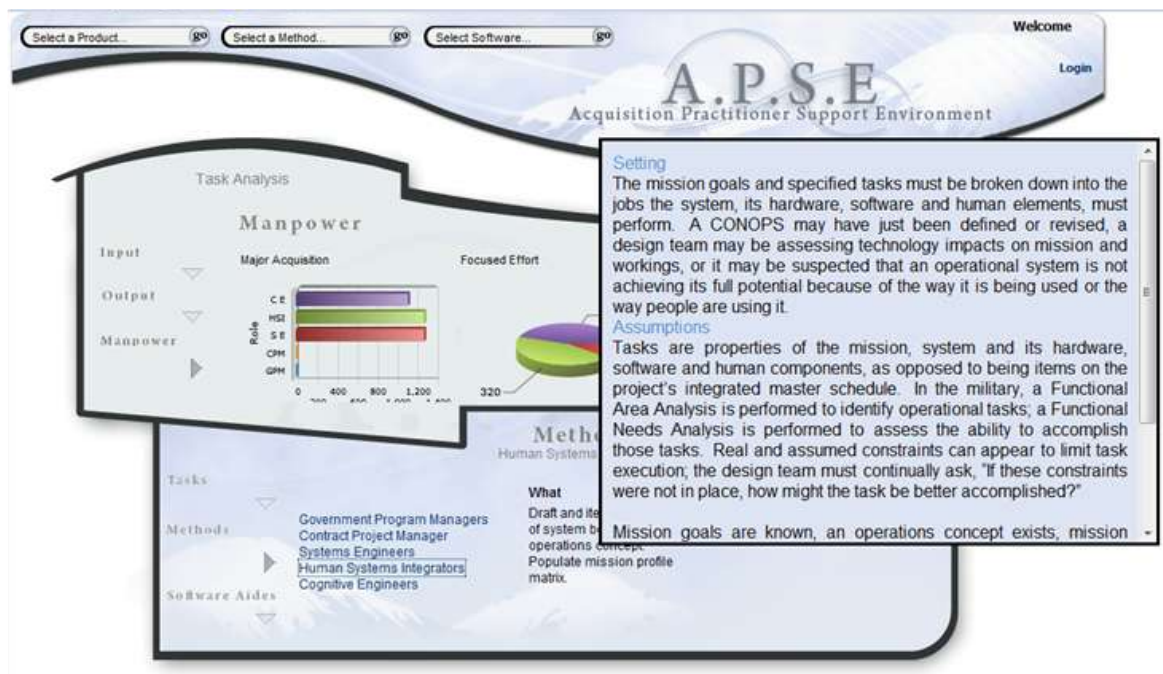


Figure 22: Sample APSE deliverables page



Input and output conditions are listed upon selection in the top field. These are provided to help with situating the deliverable in the IMP/IMS. They are also intended to support Earned Value Management plan development.

Figure 22 is configured to show the way in which the interface expands a window upon selection. In this instance, the Setting and Assumption fields are blown up. Setting describes the acquisition (project) state when this deliverable is being generated. It is designed to help cognitive engineers and human systems integrators place their work in context of the other activities that are simultaneously occurring. Assumptions provides the APSE creator's views when they populated the deliverable page. Most often assumptions were made when manhour estimates were made, so this information supports review of the APSE manhour numbers. It allows planners to understand what is different in their own situation from what was assumed in APSE.

At the bottom, lists of tasks, methods and software aids are given. This is in contrast to the main page which lists one or at most two tasks, methods or software for each deliverable. The deliverables page thus gives a more complete picture of the contributions of the represents of the APSE target audiences for the deliverable in question.

APSE describes 35 deliverables. Each is described using pages similar to those in figures 21 and 22. A phase-wise listing of the 35 deliverables is provided below.

### **Joint Capabilities Identification and Development**

Operations Concept

Task Analysis

Functional [Needs] Analysis

Joint and Initial Capabilities Documents

Analysis of Materiel / Non-material Approaches

### **Concept Refinement**

Cost (earned value)

Systems Engineering Plan with HSI Plan

Analysis of [Concept] Alternatives

Requirements (User), Specifications, Interface Control Documents

Test and Evaluation Plans

### **Technology Development and Demonstration**

Research and Development

System Concepts

Modeling and Simulation – Validating Against User Needs

Capability Development Document

Information Support Plan

### **System Development**

- Prime Contract
- Integrated Master Plan / Schedule
- Work Breakdown Structure / Integrated Product Teams / Cross Product Teams
- Trade Studies
- User Interface

### **System Demonstration**

- Training
- Developmental Test and Evaluation
- Design Reviews
- Operational Assessment
- System Verification

### **Production and Deployment**

- Analyze Deficiencies to Determine Corrective Actions
- Modify Configuration to Correct Deficiencies
- Pre-Initial Operational Capability Support Review
- Post-Deployment Review
- System Validation

### **Operations, Support and Retirement**

- Monitor and Collect All Service Use Data
- Analyze Data and Determine Root Cause
- Fix Shortfall or Include in Next Increment
- System Validation
- Retirement

#### **4.1.2. Software Demonstrations**

The software demonstrations were simulations of analyses. All looked at a university intruder security system consisting of a new chemistry lab classroom building with sensors and communications systems and a security call center. We assumed that the chemistry building and the call center were to be built simultaneously and that other buildings would later be retrofitted with devices that could be monitored and controlled from the call center.

Figure 22 shows the interface for the Micro Saint Sharp presentation. The interface was developed for DARPA's Rapid and Accurate Idea Transfer project. It is based on the Abstraction-Decomposition Space used in Cognitive Work Analysis. With more abstract concepts at the top and more detailed concepts at the bottom. In this three column format, the left column provides general information about the software aid. APSE designers provide the purposes for the software in the context of embedding cognitive systems into systems engineering practice. In the left center panel, the functions of the software are listed, for the most part taken from vendor marketing materials. At the bottom left is a link to the vendor's product web site.

At the top right, the purposes of the product demonstration are shown. These describe the integrative or collaborative attributes that can be obtained from product use. In the middle right are the steps used in the demonstration. Analysis or design artifacts for each of the steps are used to document the steps. Each of the icons on the right represents a link to a pdf, graphic or flash movie file that would appear in the center window. The use modes document is currently displayed. When a user clicks on one of the steps, the support document is displayed, full-screen in the center window. The window can be reduced to its original size if an APSE user wants to view other windows. In either configuration, scroll bars are supplied to support document navigation.

Manhours were collected for each of the demonstrations. The manhours are used to populate the graph at the top of the display where cost measures are provided for planning purposes. Below the graph is the binned retail price of the software as shown in figure 23.

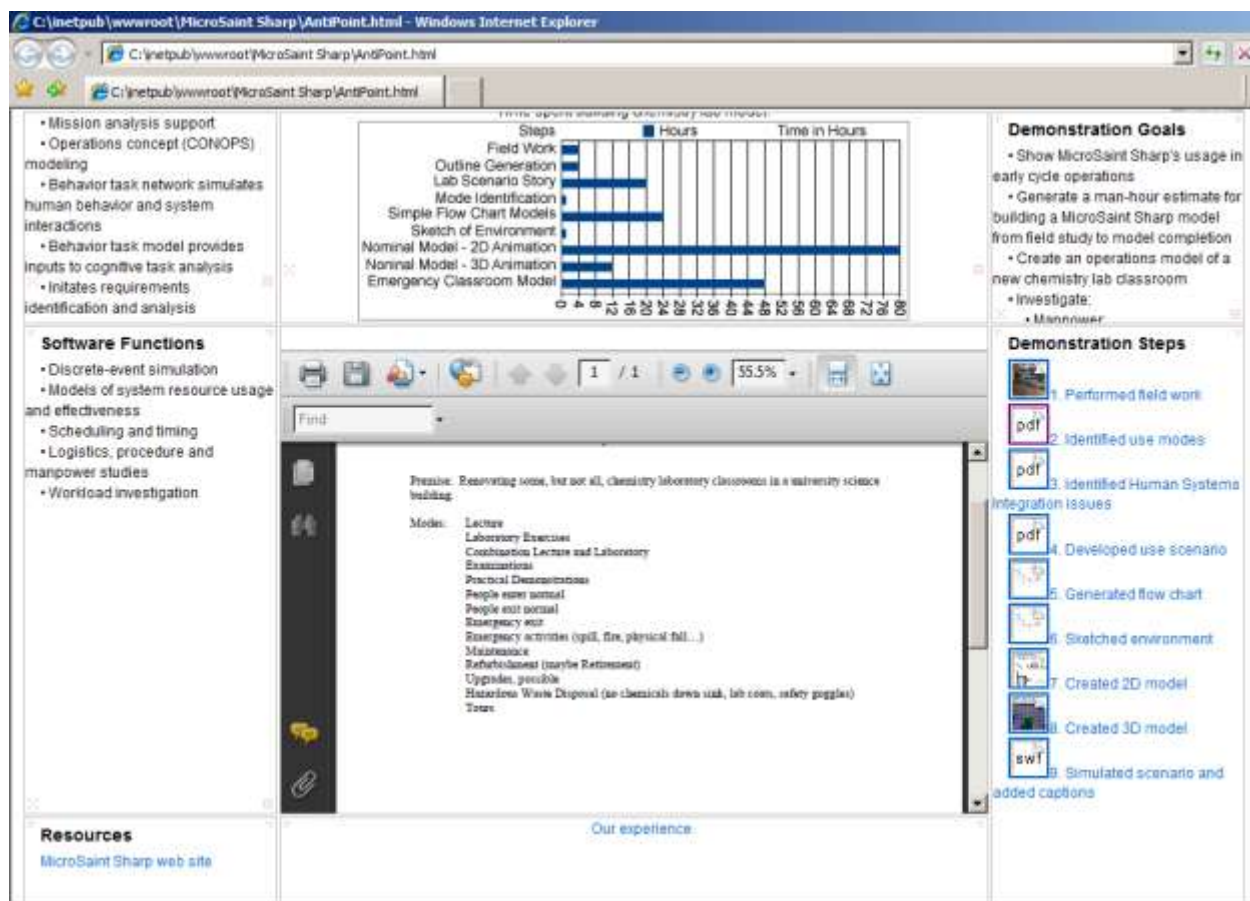


Figure 23: Micro Saint Sharp demonstration

The bottom center window provides a link to a text document that describes our experience with using the software. It notes glitches and resolutions or workarounds. It describes features or functions that would've improved usability or helped with interdisciplinary communication.

A nine-stop demonstration was conducted with Micro Saint Sharp. They included creating a two-dimensional and a three-dimensional behavior task network simulation of classroom use based on scenarios documented in step 4. The task network and two-dimensional simulation are shown in figure 24.

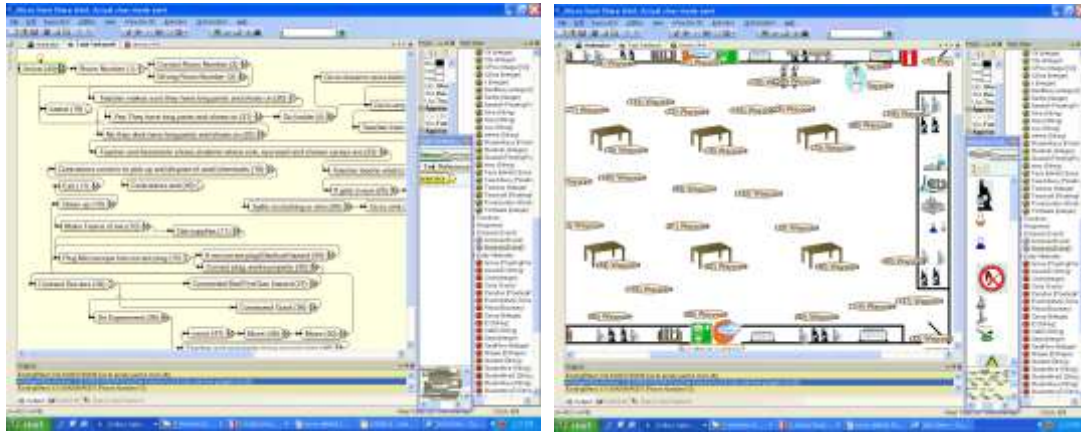


Figure 24: Micro Saint Sharp behavior task network (left) and associated 2D animation (right)

Figure 25 shows the interface for the TestLog presentation. The content is laid out in the same

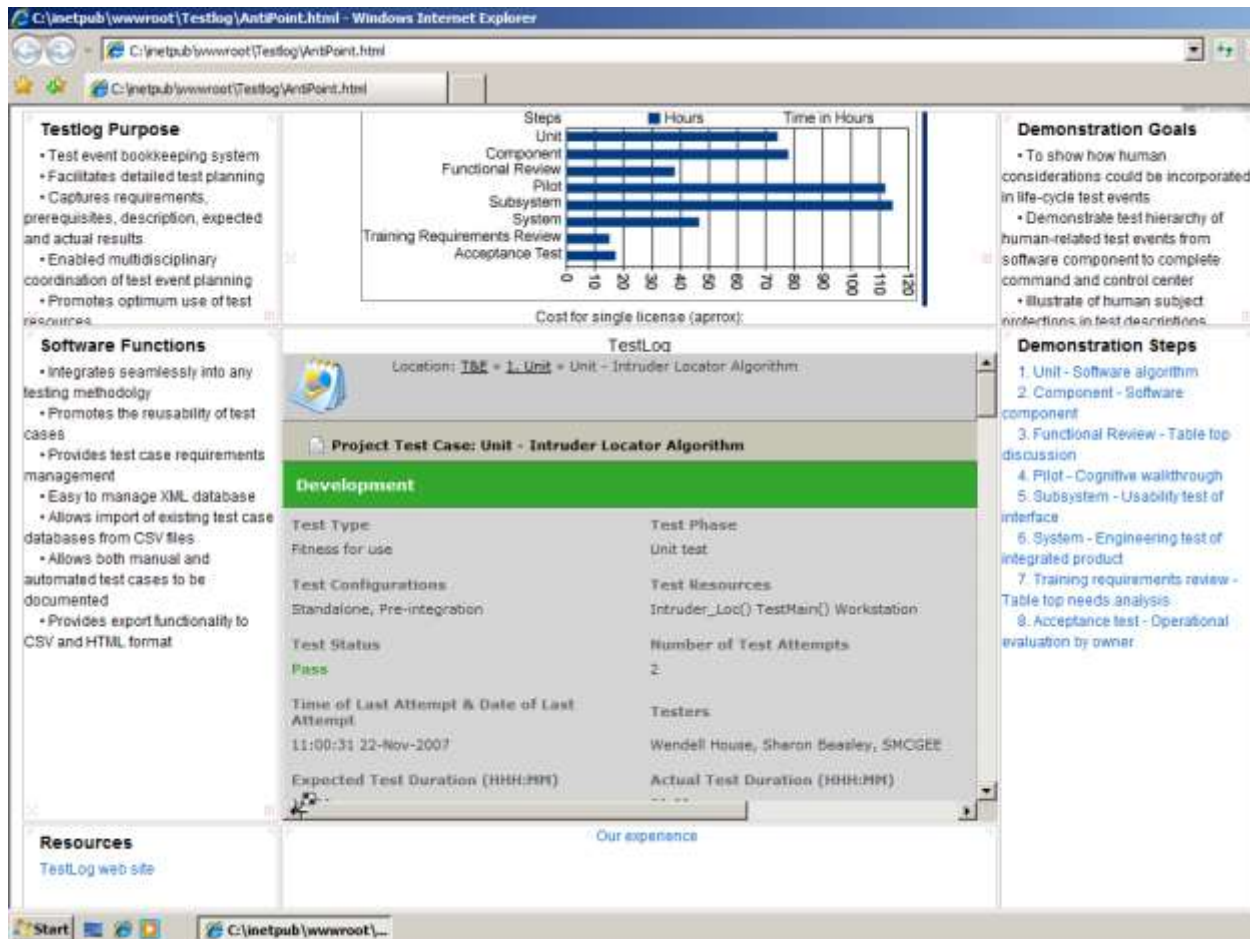


Figure 25: TestLog demonstration

manner as the Micro Saint presentation, general information on the left. Specific information about the demonstration is on the right. Six test events were created for test log. They related to the build-up of the intruder call center. Cognitive systems engineering methodologies and test subject requirements were captured in the following six test events.

1. Unit – Intruder speed estimation algorithm. Software only test of algorithm that estimates intruder locomotion as function of reported physical attributes and demographics
2. Component -- Location of intruder section of situation awareness user interface. Is assumed to integrate four algorithms to provide users with 25 percent, 50 percent and 90 percent error probability circles. Intruder speed estimation algorithm is part of this suite. Because the location function is considered a critical function of the system, a table top analysis is executed after the test event so subject matter experts can determine whether the design approach is adequate, if it incorporates the latest understanding, and if it is appropriate for both experts and novices.
3. Pilot – situation awareness user interface clickable prototype. Test plan assumes that enough of the user interface exists to execute usability tests.

4. Subsystem (integration event – situation awareness user interface, delivered product). One of the four call center workstations is tested in its fully integrated, delivery configuration.
5. System – call center. This is the fully integrated system undergoing verification testing prior to delivery. A second table top analysis is incorporated to firm up training requirements and identify any late-phase, minor changes that could be incorporated into the hardware and software that would, when traded against training costs, save the program money.
6. Acceptance – lives saved. This is the validation event conducted as part of a simulated emergency event.

Two examples of the table top analysis method was generated with example questions and simulated output tables. The first analysis was used as part of requirements validation to ensure that the design approach was satisfactory. The second was conducted as part of system test in order to capturing training requirements.

TestLog exports its documents as html files. This eased construction of the demonstration interface. Artifacts associated with each of the eight steps in the center right panel are html files created from within TestLog. This illustrates the flexibility of the presentation interface for APSE purposes. No matter the file type, this interface can accommodate it.

Task Architect, a bookkeeping aid for task analysis results, was similarly demonstrated. Thirty-six task parameters were populated for two selected tasks. Tasks were taken from the University Intruder scenario that was developed in conjunction with the Micro Saint Sharp demonstration. Task for a four-station call center were analyzed.

#### **4.1.3. Analysis of Alternatives**

Ordered Phoenix Integration Software for Analysis of Alternatives demonstration exercise  
After completing work on Task Architect and TestLog (anticipated end of April), the design team will assemble a suite of models to perform an Analysis of Alternatives related to the University Intruder scenario. We have discussed our initial plan which will include Excel models, perhaps some of the other tools we have already exercised, for example Micro Saint Sharp, and a cost model. This exercise will help to bring in measurable cognitive systems engineering attributes and provide lessons in linking cognitive systems engineering and systems engineering in this key acquisition activity.

Steps 1-5 have been previously completed. We are simultaneously working on steps 6 and 7. A architecture of models has been developed which includes 10 integrating models, one for each Measure of Effectiveness. A decision model, the Integration Model, will aggregate the results of each of the 10 integrating models in a method similar to QFD in order to deliver a “score” for each of the two alternatives we generated in the previous reporting period.

Ten Integrating Models / MOEs

- Lethality Index
- Time to Resolve and Report

- Safety Index
- Accuracy
- Affordability
- Availability
- Preparedness
- Positive Affect
- Refurbishment Efficiency
- Disposal Efficiency

Supporting the 10 integrating models, are 26 contributing models. These were identified with documented traceability to steps 1-3. We do not plan to populate all 26 of these contributing models. These would be required if the full Analysis of Alternatives described in the exercise were to be executed. Our intention is to simulate an Analysis of Alternatives that includes human considerations – how it would be constructed and executed. We plan to populate only those models that are necessary to achieve this demonstration.

The primary goal of the Call Center is to reduce the lethality of an intruder incident. The primary MOE for this is an algorithm we call “Lethality Index.” It is dependent upon attributes of the weapon, the building design, and the ability of Call Center personnel to manage the situation through manipulation and communication. In describing the model, we have defined parameters, identified their purpose in the analysis, described the calculation method and identified contributors, such as a weapons database.

A similar approach was taken for a “Time To Resolve and Report [Intruder Incident]” model. In order to develop this timeline model, an analysis scenario was created. This scenario is neutral to the two alternatives being analyzed. It describes observable intruder actions and goals.

The timeline model motivates a simulated cognitive walkthrough of storyboards. Staffing profiles were determined as part of alternative definitions. A database of individual and team cognition results is being generated. Statistics from this database, the User Interface Test Model, will feed into the integrating Accuracy model as well as the Time to Resolve model.

Simultaneous with the User Interface Test Model a Manpower, Personnel and Workload model is being developed. Individual tasks taken from the timeline are aggregated into team tasks. Roles, responsibilities, skills, knowledge and aptitudes are defined. A human capital objects model is used to generate a proficiency rating. When the proficiency rating number is compared with incumbents or the target population, this enables an estimate of compensation required to hire a person with this proficiency or the investment in training required to grow a person with this proficiency from the pool of qualified incumbents. Thus, this impacts the Affordability MOE in addition to Accuracy.

A walkthrough of progress was conducted with Klein Associates personnel. Suggestions for improvement were made. Subjectively the feedback was this was a very exciting approach. All parties wished this exercise had commenced at the beginning of Phase II as there has been a great deal of learning from it already.

## **4.2. Market Development, Awareness and Education**

Meetings were planned, lead and attended. Papers were written and presented. The HSIWG was founded, organized, documented and energized. Cross-disciplinary and cross-organizational connections were made. These activities were sometimes referred to as marketing, sometimes as social engineering.

We succeeded to some extent in getting practitioners and organizations to look beyond themselves. Members of INCOSE, IEEE and HFES were interacting and exchanging ideas. They were sharing plans. An MOU between INCOSE and HFES was initiated and is in review.

The IEEE papers (3) (29) to which we contributed pushed reached audiences with messages that were elementary to systems engineers, but were considered paradigm shifters by the cognitive engineering people.

We demonstrated that deliverables, not process, represented points of integration. People do not work at the process level. Practitioners, even when they are only systems and specialty engineers, interact on the products they must produce together. This philosophy was shared with Dr. Gavan Lintern during his development of a Cognitive Systems Engineering – Systems Integration workshop.

Dr. Lintern was invited to give a workshop to South African systems engineers. He asked that we review the approach. He had intended to present at the process level, but was convinced to address the integration at the product level following the APSE approach. His acceptance of this approach enabled us to suggest incorporation of the lessons and formative suggestions that were developed as part of this contract. The workshop was very well received, and Dr. Lintern plans to seek other opportunities to give it.

### **4.2.1. HSIWG**

Starting from two members in January 2006, the organization has grown to over 150. The bylaws drafted by this report's author in February 2008 and adopted by membership in March included provision for people from organizations outside INCOSE to participate in the group as adjunct members. This clause laid the foundation for adoption of a policy similar to that of HFES. For a nominal annual fee (< \$20), anyone may join and participate in an HFES technical group. This is a mechanism for breaking down the walls between specialties that are barriers to needed solutions.

INCOSE is on record as stating that humans must be treated within the system design boundary, that HSI is an integral part of systems engineering. Some INCOSE members have stated they believed HSI would BE systems engineering in another 10 to 20 years.

The HSIWG is working with the requirements group to establish guidelines for the development of HSI requirements. At the Assistant Secretary of Defense levels, standards for HSI practice are



being developed. These are useful, but requirements statements and RFP language represent contractual comments that must be satisfied. Requirements the vehicle by which system attributes, which include human contributions and constraints, will fulfill mission needs, address capability gaps and make fielding these systems more affordable over their operational life.

The Hoffman-Deal paper (29) made clear the differences between informing design and specifying design. The former is not enforceable; it has no teeth. APSE' pages on configuration management explain the process for modifying requirements and specifications during a program's execution. Together, this information should help cognitive engineers to impact designs with their work products and to understand how the findings from continuous learning can be incorporated in the development process.

Shall statements are not the only way in which a system can be specified. HSIWG is also working with the Model-Based Systems Engineering (MBSE) Working Group, individuals who believe dynamic models of systems are more fruitful and accurate ways of delimiting system features. This relationship places new demands on cognitive engineering and HSI community.

The MBSE community seeks cognitively accurate models of agents placed in their systems models. They would like to answer the question, "What happens when you put 160 colonels inside a one-acre area?" as is done with an air operations center. Personality types, conation, and affect will need to be incorporated in these models. Advocates of MBSE are communicating their needs; members of the cognitive engineering community have said no one can do that today. It remains to be seen whether they will be able to do that tomorrow.

The benefits of the collaborative HSIWG aside, it may be approaching a leadership crisis. Chairing a diverse group of that size is enormously demanding. Few professionals feel they have the time to do the job properly. Elections to be held this April, may determine whether the group will continue.

#### **4.2.2. I/ITSEC Booth**

I/ITSEC entertained about 16,000 visitors and over 400 exhibitors. Our goal was to set up a very humane booth in the midst of electronic overload. Our neighbors boasted multiple, huge video displays, large simulators, models, alcohol, explosions and target shooting which, if separated, would've been manageable.

Figure 26 shows the APSE booth. Two computers enabled us to give product demonstrations or for people to try APSE for themselves. None of the visitors chose the latter. People who did stop preferred us to demonstrate the tool. The promotional video was run continuously to attract the attention of passers by. An easel containing a flip chart held many different messages during the conference. The contents of the message changed based on engagements and discussions with booth visitors. Our plan was to look like a library with comfy chairs in which people could rest and review the product. Few took the opportunity to rest.

Many people walked by our booth without a second look. A booth designer came by just to look at it and marvel at the simplicity and attractiveness of the design. Several very enthusiastic people stopped and talked for extended periods. Those who stopped with interest were shown a

demonstration of the product. For example, representatives of SPAWAR were very interested in APSE, said they had done something similar but that it didn't have nearly as good an interface as APSE.



Figure 26: The APSE booth at I/ITSEC

Below, in Table 10, is a list of individuals who either stopped by the booth with interest in HSI or CSE or in APSE particularly or who were engaged during walkarounds of the floor.

During walkarounds Deal Corp personnel engaged vendors in discussions about how they fit into the human systems integration framework, their incorporation of cognitive attention and decision-making principles and cognitive systems engineering and their use of task analyses in defining training or other product requirements. Most of those engaged were not aware that Training was a component of human systems integration. They accepted requirements in an “over-the-wall” fashion saying, ‘Give us your requirements and we’ll apply our technology to developing training products.’ Prior to the conference, we assumed we would encounter a block of technology that was divorced from the needs of the end user. That was also our conclusion as we left I/ITSEC.

In addition to the booth and floor walks, we networked with people at lunch and between presentations. The idea was to make people aware of human systems integration, cognitive engineering and APSE. We had calling cards printed with the product name, purpose and URL. Deal Corp was not promoted on the calling card in keeping with our efforts to avoid branding product for fear that a “not invented here” syndrome would reduce its use.

Table 10: Booth Visitors or Other Engaged During Floor Walks

<b>Name (last,first)/Title</b>	<b>Affiliation</b>
Bryant, Chris Director Human Systems Integration	Sys Technologies
Catlett, David Director	Center for Transformative Research
DeBargis Senior Manager	Lockheed Martin Canada
Decker, William M. Director, Technology Transition Learning Center of Excellence	Defense Acquisition University South Region
Goodman, Michael S.	General Dynamics C4 Systems
Gordon, Doretta E. Ph.D. Acting Director Emerging Training & Performance Technologies Department Training, Simulation and Performance Improvement Division	Southwest Research Institute
Green, Olin S., Jr. Sr. Architect Defense Technologies	Kratos, Defense and Security Solutions
Kauchak, Marty Editor Military Training Technology	KMI Media Group
Sampson, Thomas, LT Asst. Fleet Aviation Training Systems	Chief of Naval Operations, N882B2A
Smith, Eddie B.	RAVLLC
Steinman, Jeffrey S. Ph.D. President & CEO	WarpIV Technologies, Inc.
Tubell, Wally Professor of Engineering Engineering and Technology Department	Defense Acquisition University South Region
Walrond, Col Thomas United States Air Force	Joint Forces Command Joint Warfighting Center
Waters, Matt JPA Program Lead Contractor	DLA/DAPS
Whitted, Gary A. Senior Systems Engineer Systems Engineering Operations	Ball Aerospace & Technologies Corp Systems Engineering Services

Subsequent to the conference, several people registered for use of the APSE web application. We also notified people from previous meetings of the availability of the tool and garnered a few additional users. At last count, however, there were still less than a dozen registered users. The concern we had about the site languishing remains a concern and something that needs to be worked after the contract's conclusion.

### 4.3. Phase III Marketing

#### 4.3.1. Testimonials

We were not able to obtain testimonials about APSE's effectiveness prior to the end of the period of performance. In part, this is because APSE pages were being populated as late as the end of November 2008. By then, the team was focusing on I/ITSEC preparations and time did not permit us to seek a user who was willing to test the product. Kelly Neville, a professor at Emory-Riddle University has said she will use APSE if she winds up again teaching the system development course she taught in 2008. If successful, this could provide one statement.

We still feel that testimonials will differentiate APSE from useful sites that have languished in the past. It is difficult thing to manage when developing products for government use, as government employees are not permitted to even appear to endorse products. A DoD prime contractor could contribute what is needed if a trial can be arranged and APSE provides value.

#### 4.3.2. Video

Figure 27 shows the opening and closing messages of the APSE movie. The problem on the left, is that customers (users) hate the new product, the system. They refuse to use it, it is costing the



Figure 27: APSE movie beginning and ending

owner a fortune. At the end, by using APSE, designers have better incorporated user and owner needs. They have a better handle on the total cost picture.

The spokeswoman for the cognitive engineering discipline describes the how APSE helps to address the cognitive requirements of work (figure 28) – critical decisions, managing uncertainty, planning and re-planning, sense making and problem detection.



Figure 28: Illustrating the cognitive requirements of work

The video introduces people to the functions of APSE when they navigate to the web site. We also plan to post it to You Tube as another avenue to drive people to the web site. The humorous ending is something that will intrigue the upcoming generation of managers and engineers.

In retrospect, it might have been advisable to generate a similarly entertaining video that more generally describes the problems that arise when human needs are excluded and the solutions that HSI and cognitive engineering offer as opposed to one that was specifically for APSE. A more general treatment could've become a sales tool for HSI practitioners, useful for demonstrating to engineers and managers the value human system engineering provides.

#### **4.3.3. Demonstrations**

The demonstrations were a non-invasive, safe approach to validating our process and product requirements. They very effectively helped us to arrive at an attractive presentation and useful content.

After the demonstration to Booz Allen Hamilton's Margaret Sampson, she noted that the APSE project addressed the following areas identified as critical by the Air Force HSIO.

- Selection of important points of intersection – HSIO has been working to identify the places in the acquisition process where HSI analysts and engineers should interact. APSE team has identified these with their deliverables list.

- Software tools linking systems engineering to HSI – HSIO adopting a survey and selection approach. APSE exercises and demonstrates how viable, existing tools can be used to make the connection. Sampson acknowledged this to be an efficient, effective approach.
- Analysis of Alternatives Approach – incorporation of human attributes in an AoA has proven elusive. APSE team believes human considerations can be included, but the data preparation stage of the AoA process will differ from that used by technologists.

As stated in section 3, we do not believe the survey and selection approach to software selection will be useful. Without exercising the software, it is impossible to determine its effectiveness. Additionally, software products, which by their very simplicity are overlooked by surveys, demonstrate remarkable capabilities for linking systems engineering and HSI. Displays of step-by-step instances of software implementation help users to envision how those products can meet acquisition practitioner needs.

We did not complete our AoA exercise. However, after reviewing APSE progress, particularly analysis of alternatives and APSE video with CHI Systems' Dr. Jennifer Fowlkes, she observed "Even if you don't finish the analysis of alternatives, just getting through [step three] the Measures of Effectiveness is amazingly valuable." We certainly achieved that and more by proceeding to step six, model construction.

## 5. Conclusions

APSE instantiates a process for embedding cognitive systems into systems engineering practice which is built upon the Defense Acquisition System. As such, it meets the topic requirement of being acceptable to the acquisition community.

There were some indications that high-powered software for designing user interfaces was desired from the contractors. Software exists for developing user interfaces. Other techniques, such as providing XML language so users can tailor their own interfaces, are in hand or in progress. These do not solve the problem of linking the interfaces to user needs. Additionally, configuration control would be difficult with such tools and could create vulnerabilities particularly in a system-of-systems environment.

Cognitive engineering researchers at the CHI/ihmc meeting in October 2007 sought a definition of human systems integration that would allow their research to flourish and to be incorporated in system design. This does not recognize the realities of the current environment. It is an approach that does not provide a path to incorporation of cognitive engineering in systems engineering practice. It could be advantageously disruptive, but it would be difficult to implement.

During meetings at Glen Helen in phase I (20), the desire to remove the artistry from cognitive engineering was expressed. It is our opinion that the opposite course will be more profitable. We need to accept the challenge of building better artists. That suggests an institutionalized educational solution, but that approach is not necessarily the answer either. Universities are not contrived to provide interdisciplinary education. At MIT, the aerospace engineering curriculum includes a course called “Unified Engineering.” At one time, the course work of fluid dynamics, mechanics, structures, etc. were conceived to be concurrently taught and integrative problems sets assigned. In practice, each discipline was taught independent of the others. Problems sets were populated with exercises specific to each field.

During the 2008 HSIWG meeting, integrative college curriculums were reviewed. We observed a similar approach being taken. The necessary topics were individually present, but the means to bring them together was lacking.

APSE takes an approach that has been shown by Defense Acquisition University to satisfy user needs. Continuous learning modules provide information required to do the job at end when that information is needed – just-in-time education. This tactic can reach people who are developing, operating and sustaining systems today. We may not have to wait until a generation of properly trained HSI, systems engineering and cognitive engineering becomes available.

That being said, it was asserted by Dr. Robert Hoffman that the current generation of acquisition specialists must pass before meaningful change can happen. It is our observation that the same can be said for the current generation of cognitive engineers. The founders are bound to their research backgrounds. They enjoy theoretical discussions and debate. Their productivity is measured in published papers. As has been discussed, these individuals are not able to directly influence design because technical management activities are not part of their practice. They

can't write specifications that translate their products into something that is useful for engineers and manufacturers.

There is a second generation of cognitive engineers in the field at this time. They are the ones who have been tasked with field work and interacting with the engineering team. These individuals, and we're proud to include them as contributors here, are experiencing the tempo, procedures, and constraints of a project. They are adapting techniques, born of research, to satisfy the driving need to get the product out the door. They are, to use Wayne Zachary's phrase, able to answer the mail.

One thing they've discovered is that there is an entity between cognitive engineers and software developers that is missing. That person is a human-computer interface designer or a graphic designer. These people are required to make the translation between analysis and production. We discovered this omission when developing the APSE interface and supplied it by hiring a graphic designer. In retrospect, the inclusion of these disciplines would've enriched the results of this endeavor.

This document is the final report for a project. The challenge presented was not treated solely as a project. Shortfalls in addressing cognitive work negatively impacts core Air Force Missions -- air combat, air mobility command, control, communications, computers/intelligence surveillance, and reconnaissance, and information warfare and space operations. This challenge is at least 50 years old. It has permutations that affect artificial intelligence and intelligent agent design, automation and modeling and simulation to name a few. We assumed the Air Force wanted the problem solved, and we undertook to retire it.

Our approach was an aggressive one. We combined work outside the contract with elements in our work statement and the results of each to advance both. APSE does is not all that it could be. There are things we'd intended to include that were not achieved. As Margaret Sampson attested, APSE addressed some of the most difficult issues preventing integrated HSI practice -- integration points, software and the Analysis of Alternatives.

We believe we have benefited the systems engineering, cognitive engineering, human systems integration and program/project management fields substantially. When we started there was little or no recognition of the importance of human systems integration and cognitive engineering that would let alone a market for new software products. The cognitive engineering and human systems integration practitioners had the tools they believed they needed. The systems engineers didn't know they needed to more than they already were doing. We believe this activity has begun to open the market for new products and approaches by working across disciplinary boundaries and encouraging others to do the same. We are satisfied and gratified by the value we believe we've delivered to the Air Force, to the Department of Defense and to people who are on the receiving end -- users, sustainers and owners -- of the products we build.



## **6. Recommendations**

### **6.1. APSE**

APSE is finished, but it is not complete. We achieved a rudimentary capability that will serve to bring systems engineering and cognitive engineering together. It could be much more than it is. We recommend

- 1) The Analysis of Alternatives exercise be continued to completion. It is on the brink of delivering the value required by the Air Force HSIO office. The topic itself contains several publishable topics not only on AoA but also on the design of emergency response systems.
- 2) Additional software demonstrations be conducted. These have many advantages over the collect and collate methods that have been implemented in the past to little effect. Additionally, the “our experience” sections could result in software improvements. Arranging for a controlled demonstration of APSE. This would enable further refinement of the tool’s usability and its content. Additionally, it would provide the testimonials needed to move it from a research project into a useful tool for the field. It would also be useful to refine and validate the manhour estimates in the tool. Reopening communication with people contacted at the beyond Phase II conference could create an appropriate venue.
- 3) Continue marketing APSE. Take it INCOSE Workshop and 2009 Symposium, HSIS 2009, HFES 2009 and the PMI north American congress. This would not only increase usage numbers, but it allow advocacy for HSI and cognitive engineering to continue.
- 4) Engaging Defense Acquisition University. A link to APSE is a first entry to making the information available to acquisition professionals. APSE could also be converted into a continuous learning module that would supplement the current e-learning content on the site. The university does not have funds to develop continuous learning modules, but will guide the development of modules if outside funding is provided.
- 5) Work to complete a validated cost model. We had planned to meet with DoD cost estimates and reviewers to define model data requirements, algorithms and data collection process. CHI Systems coordinated a panel at HFES 2008 to discuss the topic. This raised awareness in that community, but the challenges of developing a model that acceptable to acquisition professionals will take more than a discussion among people unfamiliar with cost modeling if results are to be achieved.
- 6) Modify the tool to accept additional deliverables. Thirty-five products were selected because our findings showed them to be the most influential. Cognitive engineers and human systems integrators influence other products as well. It would be beneficial to modify the product so it could be extended.

## **6.2. APSE version 2.0**

If continued marketing shows a demand for APSE and the involved communities of practitioners continue to come together to define a joint practice, then there will be a need for software that supports their integration. We suggest that a team that included project managers, system engineers, IT architects, human systems integrators, cognitive engineers, human computer interface designers, graphic designers, software engineers, display developers, and cost modelers would be equipped to develop this high-power support.

This activity would include improving upon and confederating the software that was demonstrated during this project. We found there to be a great deal of room for improvement.

## **6.3. The Human Performance Discipline**

Practice within the human performance discipline could be strengthened by addressing needs identified during this project. We recommend:

- 1) Extend work on affect and conation. As mentioned these features are being demanded by the MBSE community. This would include personality studies and typing. Simulation agents that respond based on emotion and that can be motivated or discouraged are desired. Incorporation of these will also support development of aids to political, economic, social, information and intelligence operations. Advances would help with threat characterization.
- 2) Eliminate the notion of domains in the definition of HSI. At one time ergonomics was defined to incorporate all aspects of the human experience. Over time this was narrowed and human factors was introduced to encapsulate them all. It, too, was subject to specialization and HI was coined.

Human engineering, whatever it is called, is an inherently integrative process. Dennis Carlson, the most effective practitioner we observed, does not think in compartments, he envisions the experience of use and practices with the artifacts using physical prototypes to assure that mission and ownership goals are achieved.

We recommend that physiology, medicine, and medical delivery be included when HSI is considered. This will be difficult to do so long as HSI is regarded organizationally rather than as a process that is implemented in practice.

- 3) Replace the individuals who were champions of cognitive engineering. These projects have created a momentum that will help the Air Force to address critical missions. Information intensity is likely to grow. The thrust to introduce cognitive engineering should be intensified and not abandoned.

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## Appendix A

### List of In-Process Deliverables

	<b>Deliverables</b>
1	Acceptance Summary Report
2	Accident Risk Assessment Report
3	Acquisition Decision Memorandum
4	Acquisition Information Assurance Strategy
5	Acquisition Program Baseline (APB)
6	Acquisition Strategy
7	Advance Change/Study Notice
8	Advanced Concept/Joint Capability Technology Demonstration Proposal
9	Advanced Concept/Joint Capability Technology Demonstrations
10	Affordability Assessment
11	Alternative System Review (Customer Needs Review)
12	Analysis and Determination, Benefit
13	Analysis of Alternatives (Activity, Briefing, Plan, Report)
13b	Analysis of Alternatives Briefing
13c	Analysis of Alternatives Plan
13d	Analysis of Alternatives Report
17	Analysis of Material Approaches
18	Analysis, Behavior
19	Analysis, Criticality
20	Analysis, DOTMLPF
21	Analysis, Fault Tree
22	Analysis, Level of Repair
23	Analysis, Logical
24	Analysis, Maintenance Task
25	Analysis, Reliability-Centered Maintenance
26	Analysis, Requirements
27	Anti-Tamper Measures
28	Audit Reports
29	Beyond Low Rate Initial Production Report
30	Business Case, Logistics
31	Business Case, Open Systems
32	Business Modernization Management Program Certification Decision Package
33	Capability Development Document
34	Capability Production Document
35	Certification of Compliance with the Clinger-Cohen Act
36	Certification of Compliance with the Financial Management Enterprise Architecture
37	Change Control Board Minutes
38	Change Control Forms
39	Command, Control, Communications, Computers and Intelligence Support Plan (C4ISP)
40	Command, Control, Communications, Computers and Intelligence Supportability Certification

41	Communities of Interest Definition
42	Communities of Interest Identification
43	Competition Analysis for Depot-Level Maintenance
44	Component Cost Analysis
45	Component Live Fire Test and Evaluation Strategy / Report
46	Concept of Operations
47	Concept Selection
48	Configured Items
49	Consideration of Technology Issues
50	Constraints
51	Contamination Control Plan
52	Contract Change Notice
53	Contractor Cost Data Report
54	Contractor Data Requirements List
55	Contractor Selection
56	Contractor Services for Operational Plan
57	Cooperative Opportunities
58	Core Logistics Analysis/Source of Repair Analysis
59	Cost Analysis Requirements Description (CARD)
60	Cost/Schedule/Performance Trade-offs
61	Counterintelligence Support Plan
62	Critical Path Drivers
63	Critical Program Information List
64	Data Access Mechanisms
65	Data Asset Identification and Prioritization
66	Data Management
67	DD Form 1494 Spectrum and Electromagnetic Environment Effects
68	Defense Acquisition Executive Summary
69	Deficiency Solutions
70	Design Change Request
71	Design Review and Audit Plan
72	Design Review Data Packages
73	Design Review Meeting Minutes
74	Design Verification Report (Requirements, Verification Plan, Verification Data)
75	Designed Science and Technology Information
76	Development Test and Evaluation Report
77	Discovery Metadata Catalogs
78	DoD Component Cost Analysis
79	DoD Information Technology Security Certification and Accreditation [Process]
80	DOTMLPF Change Recommendation
81	Duration of Support
82	Early Operation Assessment
83	Earned Value Management
84	Economic Analysis
85	Electronic Warfare Test and Evaluation

86	EMC Control Program
87	EMC Design
88	EMC Test Plans and Reports
89	EMC/EMI Control Plan
90	Engineering Change Order
91	Engineering Change Proposal
92	Engineering Development Models
93	Engineering Job Analysis
94	Engineering Memorandum
95	Engineering Order
96	Failure Modes and Effects Analysis
97	Failure Report (Root Cause Investigation)
98	Functional Analysis
99	Functional Area Analysis
100	Functional Block Diagrams
101	Functional Flow Diagrams
102	Functional Needs Analysis
103	Functional Requirements, lower-level
104	Functional Solution Analysis
105	Global Information Grid Implementation
106	Hardware Elements
107	High-level Operational Concept Description, OV-1 (Integrated Architecture)
108	Human Engineering Program Plan (3-6.6)
109	Human Systems Integration Strategy
110	Human-Machine Interfaces
111	Independent Cost Estimate
112	Independent Manpower Estimate
113	Independent Technology Assessment
114	Industrial Capabilities
115	Information Assurance Strategy
116	Information Support Plan
117	Information Supportability Certificate
118	Information Technology and National Security Systems Interoperability Certification
119	Initial Capability Document
120	Initial Operational Test and Evaluation Data
121	Integrated Architecture and Supporting Views (list these)
122	Integrated Architectures
123	Integrated Digital Environment
124	Integrated Logistics Support Plan
125	Integrated Master Plan
126	Integrated Master Schedule
127	Integrated Support Plan
128	Integrated System
129	Integrated Systems-level EMC Test
130	Integration Requirements Document



131	Interface Control Documents
132	Interface Definitions
133	Interface Identification
134	Interface Revision Notice
135	Interference Control Requirements
136	Interoperability Certification
137	Interoperability Components
138	Interoperability Requirements Certification
139	IPT Structure (go through requirements and pull these out)
140	Job Package Authorization
141	Job Tasks with Descriptions
142	Lessons Learned
143	Liaison Engineering Orders
144	Liaison Specification Change Notice
145	Life Cycle Cost Estimation
146	Life Fire Test and Evaluation Report
147	Life-Fire Waiver and Alternative Life Fire Test and Evaluation Plan
148	Logistics Plan (see also number 125)
149	Logistics Support Analysis Reports
150	Low Rate Initial Production Quantities
151	Maintainability Demonstration Report
152	Maintainability Program Plan
153	Maintainability Demonstration Plan
154	Maintainability Plan
155	Maintainability Prediction Report
156	Maintainability Status Report
157	Manning Documents
158	Manpower Estimate
159	Manufacturing Plan
160	Market Analysis
161	Market Research Report
162	Mass Properties Control Plan
163	Metrics, KPPs, MOEs, MOPs
164	Mission Analysis Reports
165	Mission Interface Verification Plan
166	Mission Support Plan
167	Modeling and Simulation Validation
168	Modeling and Simulation Plan
169	Models and Simulations
170	Modular Open-System Approach (in Acquisition Strategy)
171	N <sup>2</sup> Diagrams
172	Net-Centric Data Architecture
173	Net-Centric Data Guidance
174	Net-Centric Data Sharing Plan
175	Net-Ready Performance Parameter

176	Operational Assessment Report
177	Operational Requirements
178	Operational Test Agency Report of Operational Test and Evaluation Results
179	Operational Test and Evaluation Report
180	Operational Test Plan
181	Operational View (Integrated Architecture)
182	Operations Interface Control Documents
183	Parts Control Program Plan
184	Parts Materials and Processes Selection List
185	Parts Screening Test Matrix
186	Parts, Materials, and Processes Control Plan
187	Performance Budget Document
188	Performance Objectives and Thresholds
189	Performance Requirements, lower-level
191	Performance Specifications
192	Performance-Based Agreement, Product Service Providers
193	Performance-Based Agreement, Product Support Integrator
194	Performance-Based Agreement, Product Support Providers
195	Personnel Rosters
196	Post Deployment Regression Testing
197	Post Implementation Reviews
198	Post Independent Analysis
199	Prime Contract(Bundle with SOW and CDRLs)
200	Process Design and Redesign
201	Product Support Plan
202	Product Support Strategy
203	Production Plan
204	Program Budget Decision Memorandum
205	Program Deviation Report
206	Program Engineering Documentation Requirements Notice
207	Program Integration Plan
208	Program Objective Memorandum
209	Program Plan (IMP)
210	Program Protection Plan (Security)
211	Program Requirements List
212	Programmatic Environment Safety and Occupational Health Evaluation
213	Prototypes
214	Quality Management and Control
215	Register Metadata with DoD Metadata Repository
216	Registration of Mission-Critical and Mission-Essential Information Systems
217	Reliability Estimate
218	Reliability Plan
219	Reliability Prediction
220	Reliability Program Plan
221	Request for Deviation/Waiver

222	Results of Testing, Experimentation and Evaluation
223	Review, Critical Design
224	Review, Critical Design – Subsystems
225	Review, Defense Acquisition Board
226	Review, Design Readiness
227	Review, Full-Rate Production Decision
228	Review, Information Technology Acquisition Board
229	Review, Initial Technical
230	Review, In-Service
231	Review, Integrated Baseline
232	Review, Operational Test Readiness
233	Review, Physical Configuration Audit
234	Review, Post-Deployment Performance
235	Review, Preliminary Design
236	Review, Preliminary Design - Subsystems
237	Review, Product Support Integrator Performance
238	Review, Product Support Provider Performance
239	Review, Production Readiness
240	Review, System Functional
241	Review, System Verification (or Functional Configuration Audit)
242	Review, Test Readiness
243	Reviews, Milestone (A, B, C)
244	Risk Assessment
245	Risk List
246	Risk Management Plan
247	Risk Monitoring
248	Roadmaps, Architecture-view-based
249	Safety/Hazards Analysis Plan
250	Schedule, Program Development (Integrated Management Schedule)
251	Security Classification Guide
252	Selected Acquisition Report
253	Service Directory(s)
254	Software Change Request
255	Software Elements
256	Software Plan
257	Software Reliability Plan
258	Software Resources Data Report
259	Software Support Plan
260	Solution Sets
261	Specification Change Notice
262	Specification Tree
263	Specification, Configured Item
264	Specification, Prime Item
265	Specification, Segment
266	Specification, Subsystem

267	Specification, System
268	Specifications, Build-to
269	Specifications, Design
270	Spectrum Certification Compliance
271	Standards List
272	Statement of Work (bundle with Contract)
273	Subcontract
274	Subsystem Requirements (under Requirements)
275	Subsystems, Hardware
276	Subsystems, Human
277	Subsystems, Software
278	Support and Maintenance Effectiveness
279	Support Environment and Locations
280	Support Strategy Review Plan Process
281	Survivability/Vulnerability Plan
282	System Maintenance – Support Profiles and Use Case Scenarios
283	System Requirements (under Requirements)
284	System Requirements Letter
285	System Requirements Review
286	System Safety Program Plan
287	System Security Engineering Aspects Identification and Definition
288	System Threat Assessment
289	System Transition to User
290	Systems Engineering Audit Reports
291	Systems Engineering Plan
292	Target Audience Description
293	Technical Performance Management Report
294	Technical Performance Measures
295	Technical Standards View (Integrated Architecture?)
296	Technology Development Strategy
297	Technology Readiness Assessment
298	Temporal Analysis
299	Test and Evaluation Master Plan
300	Test and Evaluation Strategy
301	Test, Configured Items
302	Threat Assessment Report
303	Total System Product Support Package (with Support)
304	Training Materials and Devices
305	Training Plan
306	Training Programs
307	Transition to Government Support Plan
308	Unit Cost Report
309	Validation Plan
310	Validation Reports
311	Value Engineering Change Proposals

312	Vendor Request for Information/Change
313	Verification Memoranda
314	Verification Plan
315	Work Breakdown Structure, Contractor (with Contract?)
316	Work Breakdown Structure Dictionary (with Contract?)
317	Work Breakdown Structure, Government
318	Work Order/Work Authority

**Appendix B**  
**Table of “Top Ten” (Actually Nine) Cognitive Engineering Activities**

<b>Integration Points</b>	<b>Methods</b>	<b>Intermediate Products</b>	<b>Deliverables</b>
<b>Field Studies</b>	Cognitive Task Analysis Critical Decision Method Ethnography Surveys Questionnaires Interviews	Cognitive Task Analysis Scenarios Environment Characteristics SKAs Team Dynamics	Early Operational Assessment Operational Assessment Operational Testing Operational Test Agency Report of OT&E Results Sustainment Assessments Post-Deployment Reviews Data Asset Identification User Requirements Functional Requirements HCI Design Specifications TES/TEMP Developmental Test and Evaluation Live Fire Test and Evaluation Test Events Product Support Plan Training Plan Beyond LRIP Report Full Rate Production Decision Review User Reviews Programmatic Environment Safety and Occupational Health Evaluation (PESHE) Support Strategy

<b>Integration Points</b>	<b>Methods</b>	<b>Intermediate Products</b>	<b>Deliverables</b>
<b>User Scenarios</b>	Situation Awareness Oriented Design Simulation Stop-Action Scenarios Critical Decision Methods	Scenarios New Scenarios How System Is Likely to Be Used. Scenario Events that Draw on Cognitive Processes.	Initial Capabilities Document Capability Development Document Analysis of Alternatives Integrated Architecture Views Consideration of Technology Issues Data Asset Identification Design Specifications TES/TEMP Developmental Test and Evaluation Live Fire Test and Evaluation Prototypes Metrics and Scenarios Models and Simulations Verification Plan and Execution Validation Plan and Execution Support Strategy
<b>Walkthroughs</b>	Scenario Review Information/Data Flow Review	Inputs From Team (Review) of Design Concepts and Artifacts. Consistency and Completeness Checks.	Analysis of Material Alternatives Analysis of Alternatives Integrated Architecture Views Consideration of Technology Issues Data Asset Identification Requirements Analysis User Interface Specification (XML, UML) Software Specifications Operations Concepts DoDAF Products (review) Product Support Plan Core Logistics Analysis Information Support Plan Root Cause Analysis Process Design and Redesign

<b>Integration Points</b>	<b>Methods</b>	<b>Intermediate Products</b>	<b>Deliverables</b>
<b>Task Analysis</b>	Cognitive Task Analysis	Cognitive Task Analysis Logistics Impacts on Availability Modeling and Simulation Plan Definition Development and Re- Development of CONOPS Technology Insertion Impacts Locations and Resources for Training How System Should be Operated	Operational Testing Operational Test Agency Report of OT&E Results Sustainment Assessments Post-Deployment Reviews Integrated Architecture Views Consideration of Technology Issues Data Asset Identification User Requirements Customer Requirements Functional Requirements TES/TEMP Developmental Test and Evaluation Modeling and Simulation Plan Operations Concept (Hi-Fi) Product Support Plan Core Logistics Analysis Training Plan Training Materials Competition Analysis for Depot- Level Maintenance Support Strategy



<b>Integration Points</b>	<b>Methods</b>	<b>Intermediate Products</b>	<b>Deliverables</b>
<b>User Profiles</b>	Artifact Study Contextual Inquiry Contextual Design (Work, Flow, Cultural, Sequence, Physical, And Artifact Models)	Comparison of Population Description used in Design with Actual Users in the Field Determination if User Definition has Changed as the Result of a Change in Usage Or Technology or Concept Clarification for Walkthroughs Cross Functional Team Who User Is What User Is Able to Do Identification of Needed Reasoning Skills KSAs Population Description Impacts of Career Progression Through Roles to Retirement SME Usage Preferences	Operational Testing Sustainment Assessments Post-Deployment Reviews Consideration of Technology Issues TES/TEMP Developmental Test and Evaluation Live Fire Test and Evaluation Modeling and Simulation Plan, Design and Execution HCI Design Specifications Manpower Estimate HSI Plan (may be in SEP) Training Plan
<b>CONOPS (1)</b>	CWA Modeling Simulation Micro Saint Naturalistic Decision Making Comprehensive CTA (focused CTA won't do because doesn't give end-to-end picture of system)	<b>1. Navigation Model</b> <ul style="list-style-type: none"> <li>• Bird's Eye View of system</li> <li>• Akin to a site map for a web site (a system's site map)</li> <li>• How information navigates to people.</li> <li>• In the form of a flow chart.</li> </ul>	Operations Concept Information Support Plan Integrated Architecture Views Command, Control, Communications, Computers, and Information Support Plan (C4ISP) Core Logistics Analysis/Source of Repair Analysis Human Systems Integration Plan Metrics and Scenarios Models and Simulations Net-Centric Data Architecture Net-Centric Data Sharing Plan Performance Requirements Support Strategy

<b>Integration Points</b>	<b>Methods</b>	<b>Intermediate Products</b>	<b>Deliverables</b>
<b>CONOPS (2)</b>	“What if/ing?” Qualitative trade studies	<b>2. Concept Model</b> <ul style="list-style-type: none"> <li>• This is the concept around which you’re developing the system.</li> <li>• Becomes one of the KPPs; may result in more than one KPP.</li> <li>• Driver of the system, why this concept is being developed (vs. driver of the design-cost/sched/ perf)</li> <li>• e.g., DDX: Reduced manning -&gt; quality of life (habitability)</li> </ul>	Operations Concept KPPs HSI Plan Critical Operational Issues User Requirements Functional Requirements Joint Capabilities Document Initial Capabilities Document Capability Development Document Analysis of Materiel Alternatives Analysis of Alternatives DOTMLPF Change Recommendation Key System Attributes

<b>Integration Points</b>	<b>Methods</b>	<b>Intermediate Products</b>	<b>Deliverables</b>
<b>Training Requirements</b>	Cognitive Task Analyses <ul style="list-style-type: none"> <li>• CTA</li> <li>• ACTA</li> <li>• CWA</li> <li>• ACWA</li> <li>• COGNET</li> <li>• COSIMO</li> <li>• Cognitively Oriented Task Analysis</li> <li>• Cognitive Function Modeling</li> <li>• Concept Mapping</li> <li>• Contextual Control Model</li> <li>• Course of Action Analysis</li> <li>• Critical Decision Method</li> <li>• Decision Ladder</li> <li>• Decompose, Network and Assess (DNA) Method</li> <li>• Empirical Framework</li> <li>• Goal-Directed Task Analysis</li> <li>• GOMS</li> <li>• Grammar Techniques</li> <li>• Hierarchical Task Analysis</li> <li>• Hi-Lo</li> <li>• Interacting Cognitive Subsystems Analysis</li> <li>• KADS</li> <li>• PARI</li> <li>• RPD</li> <li>• Semiotic Models</li> <li>• Skill-Based CTA</li> <li>• Sub-Goal Template</li> <li>• Task Analysis for Error Identification</li> <li>• Tasks Analysis for Knowledge Description</li> <li>• Task Knowledge Structures</li> <li>• Team CTA Techniques</li> <li>• Verbal Protocol Analysis</li> </ul> Instructional System Design Behavioral Task Analysis Time-Motion Studies Contextual Design <ul style="list-style-type: none"> <li>• Interviewing Techniques</li> </ul>	<ul style="list-style-type: none"> <li>• Knowledge, Skills and Attributes</li> <li>• Teaming Profiles</li> <li>• Descriptions of How Knowledge is Applied to Decisions.</li> <li>• Contextual Inquiry</li> <li>• Work Modeling</li> <li>• Work Redesign</li> <li>• Consolidation</li> <li>• User Environment Design</li> <li>• Test with Customers</li> <li>• Implementation</li> </ul>	Training Plan Training Requirements Training Materials Support Strategy

<b>Integration Points</b>	<b>Methods</b>	<b>Intermediate Products</b>	<b>Deliverables</b>
<b>Feature Definition</b>	Focused CTA	Descriptions of how user would use a designed and developed system. Design trade-off studies. Group dynamics description.	Design Specifications <ul style="list-style-type: none"> <li>• User interface (HCI/HMI)</li> <li>• Facilities</li> <li>• Team</li> </ul> Training Requirements Consideration of Technology Issues Critical Operational Issues Data Access Mechanisms Data Asset Identification Design Readiness Review Early Operational Assessment User Requirements Full-rate Production Decision Review Independent Technology Assessment Interoperability Requirements Operational Assessment Post-Deployment Performance Review Software Products User Reviews

## Appendix C

### Evolution of the APSE Interface



Figure 29: 37 Signals Backpackit interface

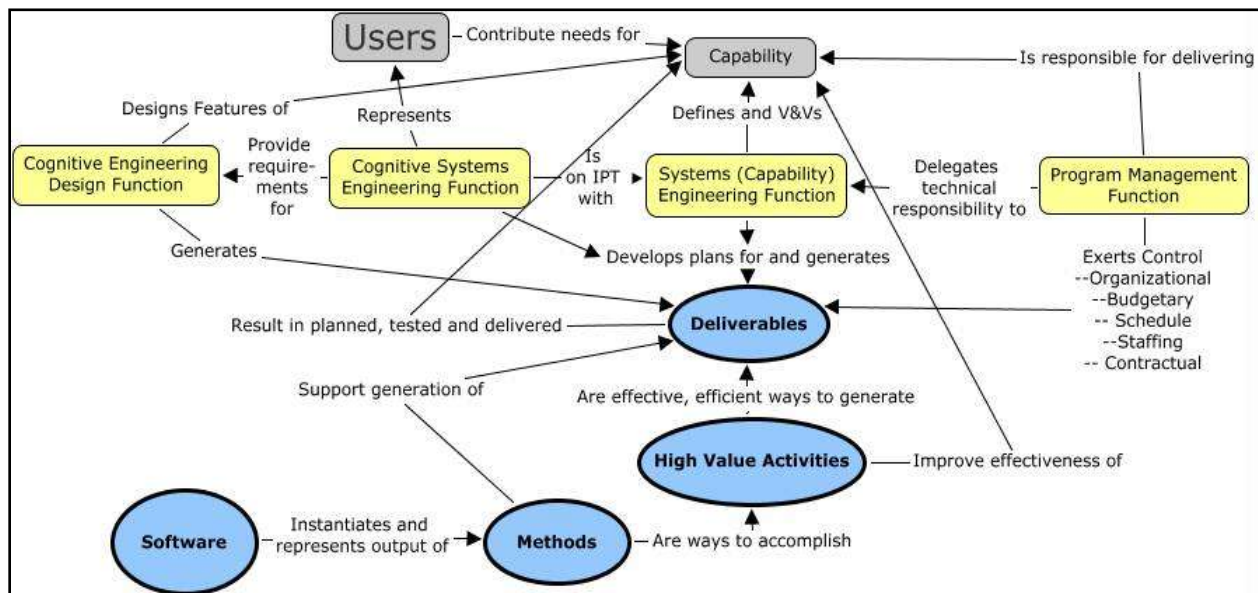


Figure 30: Concept map main page

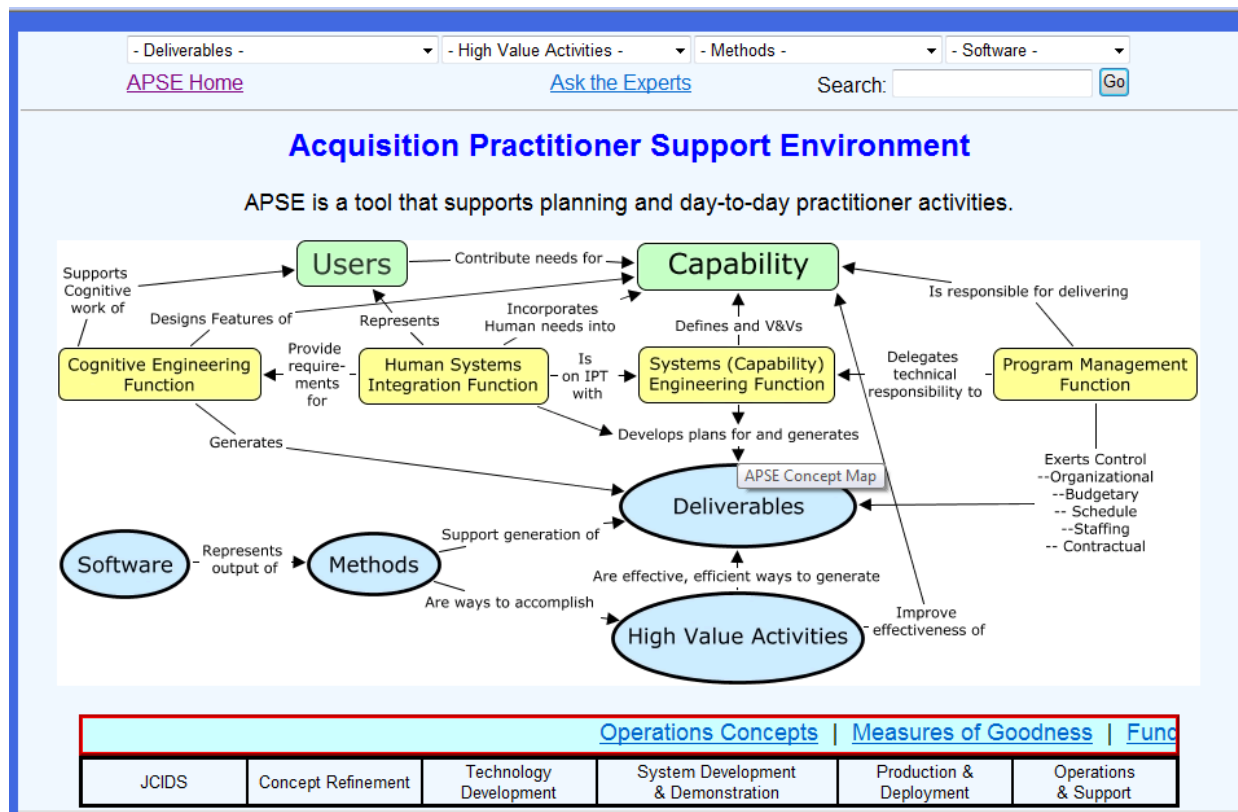


Figure 31: Concept map with high value activities and process phases at bottom.

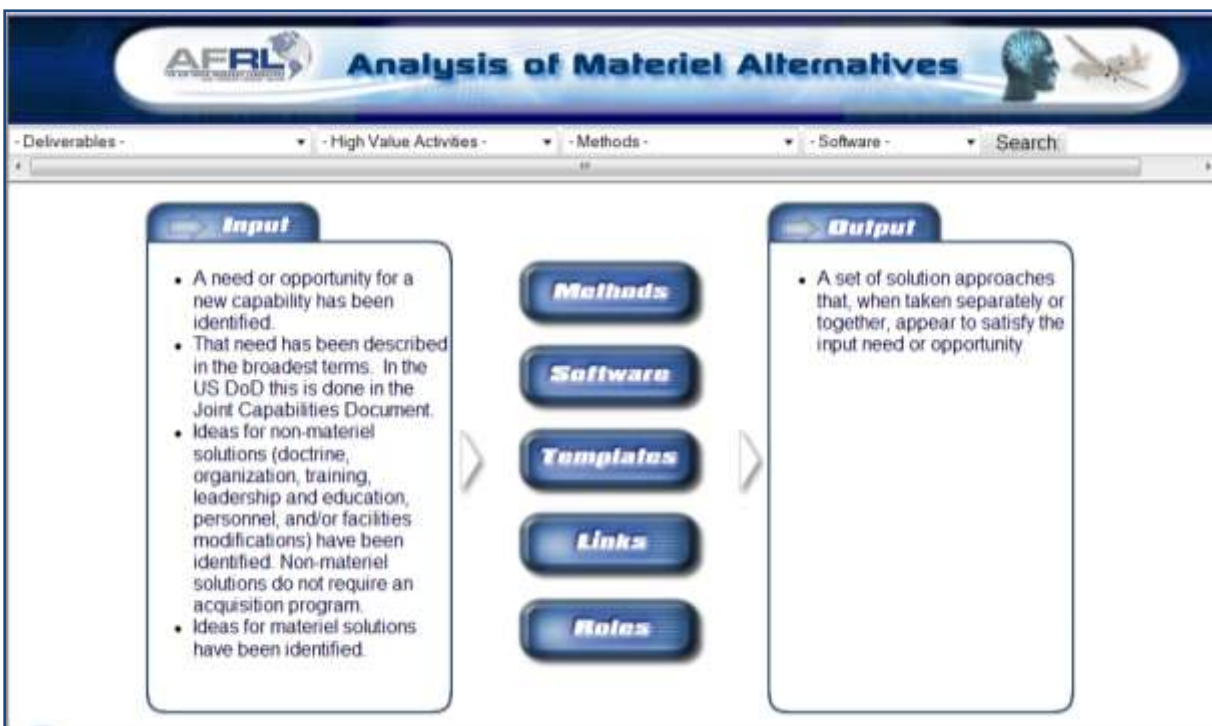
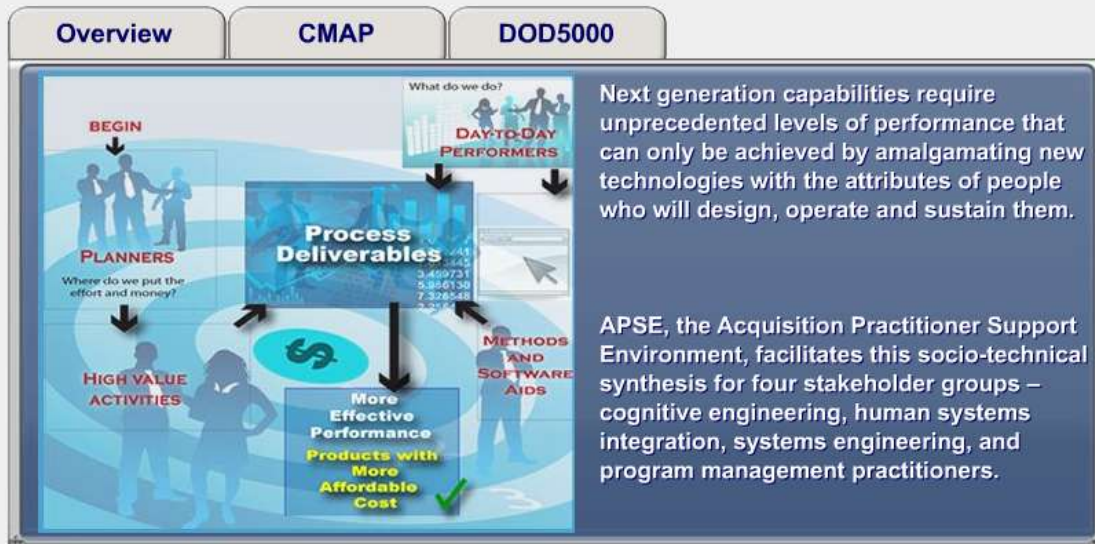


Figure 32: Input / output format for main page

*APSE shows where big returns can be had by investing in human performance, safety and satisfaction.*



<a href="#">cepts</a>   <a href="#">Measures of Goodness</a>   <a href="#">Function Analysis &amp; Allocation</a>   <a href="#">DOTMLPF Analysis</a>   <a href="#">Project</a>					
JCIDS	Concept Refinement	Technology Development	System Development & Demonstration	Production & Deployment	Operations & Support

Figure 33: Tabbed main page with selectable overview, concept map or DAS process



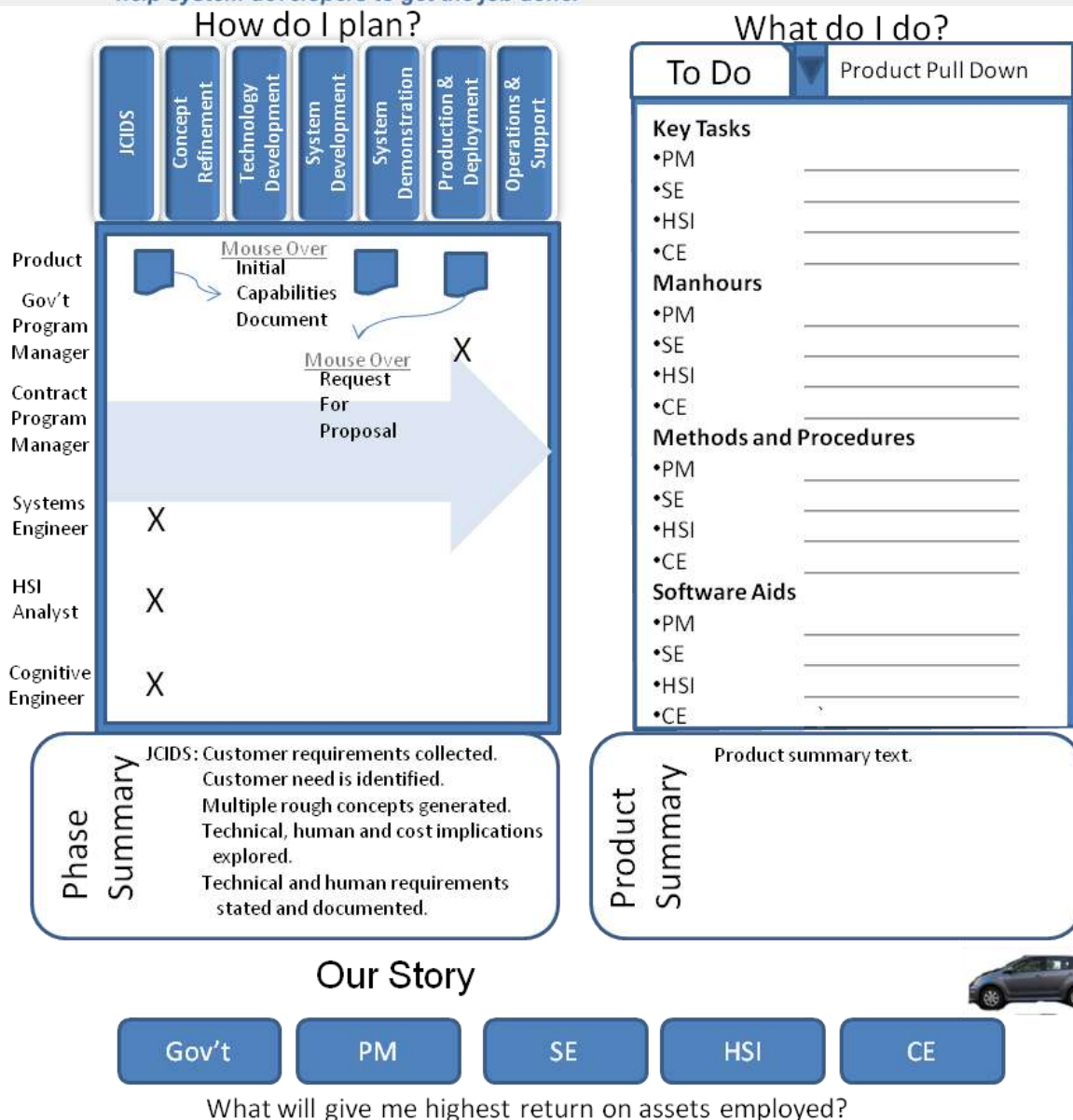
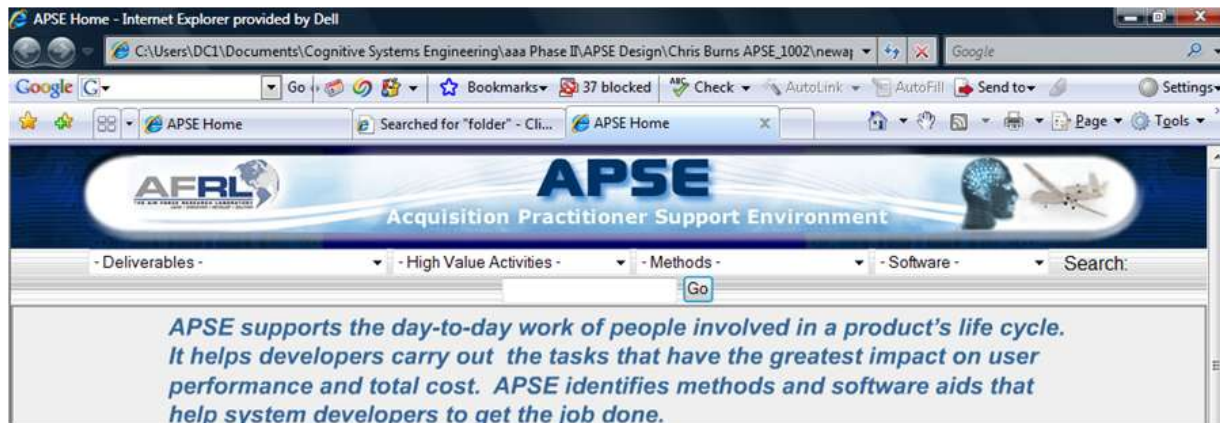


Figure 34: PowerPoint prototype devised after conversation with Dr. Fran Greene



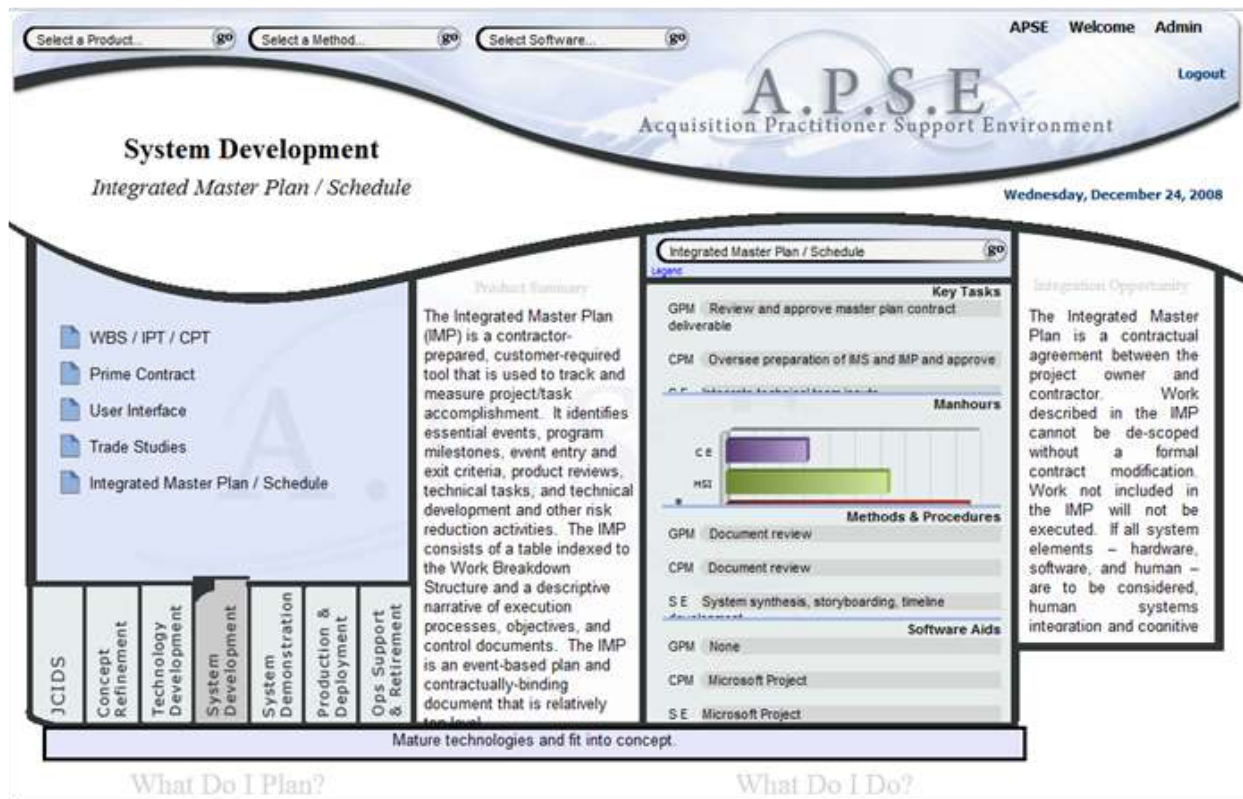


Figure 35: DotNetNuke main page designed by Brian May

## Appendix D

### Software Relevant to Embedding Cognitive Engineering in Systems Engineering

Software Name	Purpose
ABRAHAM	HSI survey tool
ADVISOR	Training design
AIM	Training material development
Altia	Interface development and rapid prototyping
AML	Loosely confederates software aids
Analyst Pro	Requirements management
Artisan Studio	UML, SySML, and DoDAF Representations
ASCENT	Capture of constraints and cognitive requirements
Belvedere	Knowledge capture and mapping
BOAT	Boxes and text support <ul style="list-style-type: none"> <li>• Behavior diagrams</li> <li>• Data and control flow</li> <li>• Functional flow diagrams</li> <li>• IDEF</li> <li>• N2 charts</li> <li>• Schematic diagrams</li> <li>• Signal flow diagrams</li> <li>• State charts</li> </ul>
Brahms	Behavior task modeling
CARE	Requirements engineering
CD Tools	Gathering, analyzing and sharing qualitative field data
CogFIT	Constructive simulation
CogniSystem	Interpretive structural modeling support
COMET/VAMOSC	Cost analysis from HCDE
Concept Star	Interpretive structural modeling support
CORE	Requirements management
Cradle-5	Requirements management
Create	Facility prototyping
CSTD	Navy-specific workstation design
Delmia	Ergonomics
Distributed Dynamic Decision Making (DDD)	Team analysis design
DOORS	Requirements management and traceability
EasyRM	Requirements management
Envision VIP	Project management
Envision/Ergo	Ergonomics
ErgoMaster	Ergonomics
FAST	Fatigue analysis
Foresight	Modeling and Simulation
Gatherspace	Web 2.0 requirements management

GRABIL	Evaluation of interface design
HCDA	Process guidance tools from HCDE
iGen	Embeddable cognitive agents
IMAGE	Function characterization from HCDE
IMPRINT	Manpower and personnel
Interchange SE	Data backbone and analysis interfaces for integrated design environments
IPME	Human performance modeling
IRqAR	Requirements management
iSight	Loosely confederates software aids
ISM	Interpretive structural modeling support
Jack	Ergonomics
KollabNet	Collaboration software
ManneQuinBE	Ergonomics
Micro Saint Sharp	Behavior task modeling
MindManager Pro	Project Management
Model Center	Loosely confederates software aids
MOST	Team design
Objectivizer	Requirements engineering
Process Model	Data and work flow modeling
Project Engine	Project management
RETH	Requirements engineering
RHEMS-D	Human-machine design based on systems engineering process
Safework Pro	Ergonomics
SALT	Spatial analysis for ergonomics
SAMMIE CAD	Ergonomics
Scenario Plus	Visualization add-on for DOORS
SEEC/Tiger Pro	Educational tool for system and software engineering
Ship-SHAPE	HSI analysis (not for sale)
SkillsNet	Navy-specific job analysis
Statestep	Software engineering requirements elicitation, specification and validation
TacWISE	Collects, integrates and analyzes performance data
Task Architect	Bookkeeping of task attributes
Taxonomic Workstation	Taxonomy manipulation (defunct)
TIDE	Organization design from HCDE
Total Crew Model	Navy-specific manpower modeling
WIBNI	Freeware requirements management database
<a href="http://www.iawiki.net/WireFrames">http://www.iawiki.net/WireFrames</a>	Wire framing useful for interface prototyping

## **List of Symbols, Abbreviations and Acronyms**

AMA	Analysis of Materiel/Non-Material Approaches
AOA	Analysis of Alternatives
AHFEI	Applied Human Factors and Ergonomics International
BOAT	Boxes and Text
CDD	Capability Development Document
CMAP	Concept Map
CogEng	Cognitive Engineering
CPD	Capability Production Document
DAG	Defense Acquisition Guidebook
DAS	Defense Acquisition System
DAU	Defense Acquisition University
DODAF	Department of Defense Architecture Framework
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership & Education, Personnel, Facilities
FAA	Functional Area Analysis
FNA	Functional Needs Analysis
FSA	Functional Solution Analysis
HCDE	Human Centered Design Environment
HCI	Human-Computer Interface
HFES	Human Factors and Ergonomics Society
HSI	Human Systems Integration
HSIO	[Air Force] Human Systems Integration Office
HSIS	Human Systems Integration Symposium
HSIWG	Human Systems Integration Working Group
ICD	Initial Capabilities Document
IEEE	Institute of Electrical and Electronics Engineers
IEWG	[INCOSE] Intelligent Enterprises Working Group
IMA	Ideas for Materiel Approaches
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
INCOSE	International Council on Systems Engineering
IPDT	Integrated Design and Process Technology
ISM	Interpretive Structural Modeling
ISP	Information Support Plan
JCIDS	Joint Capability Identification and Development System
KPP	Key Performance Parameter
MBSE	Model-Based Systems Engineering
MODAF	Ministry of Defence Architecture Framework
MOU	Memorandum of Understanding
PIA	Post Independent Analysis
PMI	Project Management International
QFD	Quality Function Deployment
SDP	Structured Design Process
SE	Systems Engineering

SEP	Systems Engineering Plan
SMCS	IEEE's Systems, Man and Cybernetics Society
SSD	Space Systems Division
TBR	To Be Reviewed